STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY

FRANK W. DE WOLF, *Chief*

EXTRACT FROM BULLETIN No. 38

FURTHER INVESTIGATIONS OF ILLINOIS FIRE CLAYS

BY

C. W. PARMELEE AND C. R. SCHROYER

Technology and tests by C. W. Parmelee
Geology by C. R. Schroyer

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URBANA, ILLINOIS
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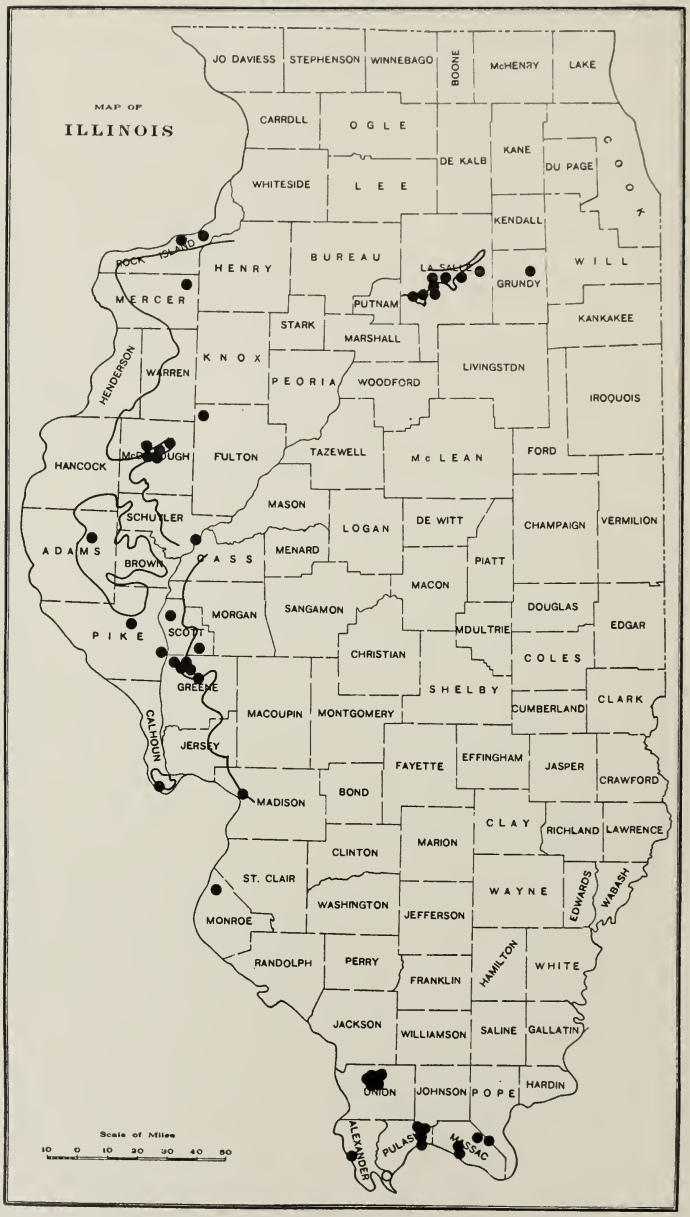

FIG. 43. Index map showing the locations of clay samples and the approximate position of the outcrop of the Cheltenham clay.

FURTHER INVESTIGATIONS OF ILLINOIS FIRE CLAYS

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FOREWORD

Very early during the participation of the United States in the World War, the importance of a better knowledge of the extent and character of the refractory clay resources of Illinois was recognized. The cessation of importations of certain types of such clays which had previously been brought from enemy countries had made it imperative that domestic clays of suitable sorts should be discovered, if possible. Further, the general disturbance of the economic life by the war had greatly increased the costs and difficulties of transportation and emphasized the necessity for a more comprehensive survey of these clays than had yet been undertaken by the State.

Consequently, Mr. C. R. Schroyer of the Survey was assigned the duty of visiting deposits, gathering the samples, and making the necessary studies of the geological conditions. Prof. Cullen W. Parmelee of the Department of Ceramic Engineering of the University of Illinois was given charge of the testing of the clays which was done in the laboratories of the department mentioned.

All known clay deposits which gave promise of being of refractory value were examined and areas which had not been previously investigated were carefully searched. Fig. 43 shows the locations of all deposits sampled.

The work was well advanced when the armistice was signed, but the cessation of hostilities was not considered a justification for termination of the investigation since it was recognized that the results would have very considerable permanent economic value. Therefore, the work has been somewhat extended and a few clays of a non-refractory type have been included since the samples were already at hand.

Since the clays of the embayment area in the southern counties of the state have proved to be of unusual interest, it was thought desirable to study their relation to the very important deposits of the embayment area in western Tennessee and Kentucky. The authors of the bulletin, together with Dr. H. Ries of the U. S. Geological Survey, visited the deposits of western Kentucky and, accompanied by Mr. Wilbur A. Nelson, State Geologist of Tennessee, visited those of the latter state.

A visit was also made to the deposits at Lutesville and Glen Allen, Missouri, in order to determine what relation, if any, existed between that area and clay deposits in the southern part of the state.

The authors therefore wish to express their appreciation of the assistance extended to them by the gentlemen named, as well as the many citizens of this State who have contributed in various ways to the successful prosecution of this work.

INTRODUCTION: A GENERAL DISCUSSION OF CLAYS

By C. W. Parmelee

The Classification of Clays

PURPOSE AND DIFFICULTIES

It is possible to classify clays in many ways; as for example, mode of origin, mineralogical character, physical properties, and uses, and several such classifications[1] have been published. The classification here presented is an attempt to correlate certain physical properties with uses.

Difficulties are experienced in such an attempt because of the incomplete state of our knowledge of clays and clay products. We still have much to learn about the properties of the unburned and the burned clays and their products.

Much information has been gathered through the agencies of the American Ceramic Society and other similar organizations, the various geological surveys, industrial laboratories, and research conducted at the various universities. Through cooperation of these various agencies, standard methods of testing are being devised and standard specifications prepared, but the task is a large one and is made particularly difficult because of our ignorance of much that is fundamental relating to the material.

One of the benefits which may be attributed to the recent war was the impetus given to the investigation of these problems. As consequences of this, not only has the knowledge of our clay resources been extended, but much has been learned about the requirements to be met by the raw materials and also the conditions which the finished product should satisfy. A better understanding of these conditions has brought about a notable improvement in the products.

Any economic classification of clays made at this time is to be regarded as only tentative, for the reason previously mentioned, namely, the incomplete state of our knowledge of the properties of the raw materials which gives them especial value in the manufacture of certain products. Further, in the consideration of such a classification it must be remembered that with the exception of certain products of the cruder sort, it is the practice to blend two or more clays which are commonly of quite different kinds, with a view to obtaining mixtures which may be formed into wares without too much difficulty or loss, and which will possess the desired properties. Therefore, in the following classification, an attempt has been made to indicate what may be called the primary uses or, in other words, those for which the clay is particularly adapted. This does not exclude clays from uses for purposes not specified. For example, a superior fire clay may be suited for the manufacture of common brick. Its primary usefulness, however, may be regarded as for firebrick since it will be most valuable manufactured into that product.

[1] Ries, H., Clays; their occurrence, properties and uses: p. 23, 1914.

A PROPOSED CLASSIFICATION[1]

The clays are classified for use according to the physical properties which give them especial value for specific purposes.

I. Clays Burning White or Cream Colored, not Calcareous

A. open burning clays, i. e., still distinctly porous at cone 15

1. Low strength, e. g., residual kaolins such as those from North Carolina
2. Medium and high strength, e. g., secondary kaolins such as those from Florida and Georgia

Clays of the open burning type are of value in the manufacture of pottery because of their good color or because of the good strength and good color. These clays are frequently of a good or high degree of refractoriness. If of a good color, they may be used for special refractories such as pots for melting optical glass; or the color may be of secondary importance and the clays may be valued for their refractoriness only

B. clays burning dense, i. e., become nearly or completely non-porous between cones 10 and 15

a. Non-refractory clays:

3. Good color, medium to high strength, medium shrinkage. Uses: Pottery, including certain whiteware, porcelains, stoneware
4. Poor color, medium to high strength, medium shrinkage. Uses: Stoneware, terra cotta, abrasive wheels, zinc retorts, face brick, saggars

b. Refractory clays:

5. Good color, medium to high strength, medium shrinkage. Uses: Refractories, especially for glass, if they do not overburn seriously for 5 cones higher. Also uses stated in 3

C. dense burning clays, i. e., become nearly or completely non-porous between cones 5 and 10 and do not overburn seriously at 5 cones higher than the temperature at which minimum porosity is reached

a. Non-refractory clays:

6. Good color, medium to high strength, medium shrinkage; usually reach minimum porosity between cones 5 and 8. Type: Ball clays. Uses: Pottery, whiteware, porcelain, and stoneware
7. Poor color, medium to high strength, medium shrinkage. Uses: Stoneware, terra cotta, abrasive wheels, zinc retorts, face brick, saggars

b. Refractory clays:

8. Non-porous or practically so at cone 5; do not seriously overburn for 12 cones higher; highly refractory; softening point at cone 31 or higher; bonding strength minimum 325 pounds per square inch. Use: Graphite cucibles for melting brass.[2]
9. Non-porous at about 1275° C. (cone 8), not overfiring at 1400° C. or higher. Strength and softening point as above[2]. Use: Steel crucibles
10. Become dense at about 1275° C. (cone 8). Do not overburn below 1425° C. Bonding strength, 250 pounds per square inch or higher. Softening point, cone 29 or higher[2]. Use: glass pots

[1]This classification relates only to the uses of clays for burned products and consequently no consideration is given to its uses as filler for paper or cloth, as a pigment, etc.
For a definition of the terms "refractory" and "non-refractory" as used in this classification and throughout the report, see page 13. For the terms "medium" and "high strength," see page 22 et seq.

[2]See page 16.

II. Buff Burning Clays

A. refractory clays

a. Open burning, i. e., having a porosity of 5 per cent or more at cone 15 or above:

Indurated—non-plastic or slightly plastic unless it has been weathered. Type: flint clay.

11. Normally aluminous; maximum alumina 40%. Use: Refractories
12. Highly aluminous; alumina exceeds 40%. Type: Diaspore clay. Uses: Refractories, abrasives

Plastic

13. Normally siliceous; maximum silica not exceeding 65%. Uses: Firebrick and other refractory wares, terra cotta, sanitary ware, glazed and enamelled brick (see specific requirements for these below)
14. Siliceous; having a silica content above 65%. Type: Many of the New Jersey fire clays. Uses: Firebrick and other refractories

b. Dense burning between cones 10 and 15, i. e., attaining a minimum porosity of 5% or less within that range:

15. Medium to high strength. Do not overburn for 5 cones higher than point of minimum porosity. Uses: Glass pots and other refractories; also used for firebrick, saggars and miscellaneous refractories, architectural terra cotta, sanitary ware, enamelled and face brick

c. Dense burning, i. e., attaining a porosity of 5% or less at cone 10 or lower:

16. See 8
17. See 9
18. See 10

These three classes, 16, 17 and 18, are used also for zinc retorts, firebrick, saggars, and miscellaneous refractories, architectural terra cotta, sanitary ware, enamelled and face brick

B. non-refractory clays

a. Open burning, i. e., do not attain a porosity of 5% or less at any cone lower than cone 10:

19. High or medium strength. Uses: Architectural terra cotta, stoneware, yellow ware, face brick, sanitary ware
20. Low strength. Use: Brick

b. Dense burning, i. e., attain a porosity of less than 5% at cones lower than 10:

21. High or medium strength. Uses: Architectural terra cotta, stoneware, abrasive wheels, sanitary ware, face brick, paving brick

III. Clays Burning Red, Brown, or Other Dark Colors

A. open burning clays, i. e., those that do not attain low porosity at any temperature short of actual fusion

22. Medium or high strength. Uses: Brick, drain tile, hollow blocks, flower pots, pencil clays, ballast
23. Low strength. Use: Brick

B. dense burning clays

a. Having a long vitrification range (5 cones):

24. High or medium strength. Uses: Conduits, sewer pipe, paving brick, floor tile or quarries, electrical porcelain, cooking ware, silo block, art ware, face brick, architectural terra cotta, roofing tile
25. Low strength. Uses: As dust body in the manufacture of electrical porcelain, floor tile, building brick

b. Having a short vitrification range:

26. High or medium strength. Uses: Building brick, face brick, hollow block, flower pots

c. Fusing at a low temperature, approximately cone 5, to form a glass:

27. Slip clays

IV. Clays Burning Dirty White, Cream White, or Yellowish White

28. Containing calcium or magnesium carbonate or both. Never reach very low porosity. Have a very short heat range. Use: Common brick

Types and Uses of Clays

In the "Clay Classification," references are made to certain types of clays which have been found adapted to special uses. In the following brief descriptions an endeavor is made to state the characteristics of such. However, the fact that a clay is designated a terra cotta clay or a sanitary ware clay, for example, does not necessarily mean that the clay constitutes a distinct type, and the attempt has been merely to describe the kind of material which is sought for the use indicated. As a matter of fact, for many purposes it is quite impossible to define the characteristics closely.

KAOLIN OR CHINA CLAY

The true kaolin is residual in its origin. It has a low degree of plasticity, low strength, low shrinkage both in drying and burning, and after purification by washing is refractory. The term kaolin is used in this country for the same type of material as that designated by the English potter as china clay, and kaolins are used for the same purposes as china clays. Since there would be an advantage in introducing a distinction between the terms, it has been proposed to restrict the term kaolin to the crude material and china clay to that which has been purified for the market.[1]

Kaolins do not always burn white. Some that are so badly stained that they are unsuited for use by the potter, may have considerable value if refractory. True kaolins have not been found in the State, nor is there much likelihood of such a discovery. The so-called kaolins of Union County are misnamed.

SECONDARY KAOLINS

These differ in origin from the true kaolins in that they have been transported from the place of origin by water and laid down in extensive beds. They are more plastic, stronger, and have higher shrinkages. They burn white, although not quite equalling the best residual kaolins. They are adapted to uses similar to those of the true kaolins.

[1]Mellor, J. W., A note on the nomenclature of clays: Trans. English Ceramic Soc. VIII, p. 23.

BALL CLAY

These are highly plastic, strong clays which burn cream white or a very light buff and vitrify between cones 5 and 10, so that they are non-absorbent. No ball clays have been located in Illinois, although the so-called kaolins of Union County have the characteristics of this type. It is possible that some of the stoneware clays of the State may be of a sufficiently good quality after washing to permit their use for some of the purposes for which ball clay is suitable. Ball clays are sedimentary in their origin. The drying shrinkage is ordinarily less than 10 per cent; the modulus of rupture as determined by the cross-breaking strength test varies between 200 and 500 pounds the square inch, with an average of 350 pounds; the tensile strength per square inch varies between 125 and 150 pounds; the total shrinkage at cone 10 varies between 16 and 20 per cent. The water of plasticity varies between 27 and 43 per cent with an average of 32.6 per cent.

REFRACTORY CLAYS

Clays are designated as refractory if they are capable of withstanding high temperatures without showing signs of fusion such as deformation, i. e., loss of shape, or softening to a fluid state.

Since all clays are able to withstand relatively high temperatures, and since no standard has yet been adopted, it becomes necessary to define more precisely what is meant by the term refractory clay. Purdy[1] and Bleininger[2] have suggested cone 26, and Ries[3] has named cone 31 as the boundary between the refractory and the semi-refractory clays with cone 27 as the lower limit for the latter clays. For purposes of this bulletin, all clays which fuse at cone 27 or higher are considered to be refractory and those which fuse at cone 33 or above are classified as highly refractory.

The term fireclay has come to be used in a broader sense than is connoted by mere refractoriness. It is now applied, at least in the middle west, to clays which have some of the characteristics of the true fireclays without regard to their ability to withstand very high temperatures. Commercially they have been divided into three classes which are known as No. 1, No. 2, and No. 3. The separation into these three grades has to a large extent been left to the convenience of the miner who wishes to make a distinction between materials but lacks the means for differentiating explicitly. Some attempt has been made to standardize these terms: for example, Bleininger[4] prescribes the lower limit of the softening temperature of No. 1 fireclay as

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[1]Purdy, R. C., and DeWolf, F. W., Preliminary investigation of Illinois fire clays. Ill. State Geol. Survey Bull. 4, p. 149, 1907.

[2]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 15, 1912.

[3]Ries, H., The clays and clay industry of New Jersey: New Jersey Geol. Survey, Final Rept. Vol. VI, p. 311, 1904.

[4]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 44, 1912.

cone 32; and further, according to Purdy,[1] the time-temperature rate of vitrification is very slow so that it attains a low porosity only at a very high temperature, if at all.

The term No. 2 fireclay is peculiar to the middle west. Not infrequently it is used by a clay miner to designate a grade which is inferior to the best which he is mining. However, the term is most frequently employed to designate a clay which burns to a light color—a cream, buff, or light tan—and attains a low porosity at some temperature between cone 5 and cone 11. These limits have been arbitrarily set by the writer since, with the exception of some work done by Purdy[2] no attempt has been made to define the term with exactness. These clays are somewhat less refractory than the No. 1 grade and burn to a dense structure which makes them unsuited as the chief clay component for the manufacture of the best grade of firebrick. The fact that the term No. 2 fireclay in some cases connotes "second-grade" and the fact that use of this clay in the manufacture of this particular product is limited, should not be misunderstood and the class consequently undervalued, for amongst these No. 2 fireclays some of the most useful of the fireclays are found. The refractory clays of this class which have high strength are indispensable in the manufacture of crucibles, zinc retorts, and glass refractories, and those of good strength are necessary as the bonding agent for the No. 1 fireclays in the manufacture of the best grade firebrick.

According to Mr. Purdy[3] the No. 2 fireclays may fuse as low as cone 16 and may be as high as cone 26, which is the minimum refractoriness of a No. 1 fireclay. Bleininger[4] states that "There is no sharp distinction between the No. 1 and the No. 2 fireclays, and any lower limits that may be set must be, in the nature of the case, arbitrary." Further he states[5] that "cone 28 might be considered the limit below which a satisfactory bond clay should not soften." This is not incompatible with the experience of Mr. Purdy[6] since he found that the "fusion point [of the No. 1 clays] in the majority of cases does not exceed that of the so-called No. 2 fireclays."

It would seem from the above references that there is much confusion in the use of the term No. 2 fireclay. In the opinion of the writer, the term should be abandoned in technical literature and its use otherwise discouraged for two reasons: (1) it carries with it an implication of inferiority which is most unfortunate since many of the clays which may be grouped under this class are quite as valuable and indispensable as those which we call the No. 1 fireclays; and (2) it makes no distinction between the refractory clays

[1]Rolfe, C. W., Purdy, R. C., Talbot, A. N., and Baker, I. O., Paving brick and paving brick clays of Illinois. Ill. State Geol. Survey Bull. 9, p. 270, 1908.
[2]Op. cit., p. 272.
[3]Purdy, R. C., and DeWolf, F. W., Preliminary investigations of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 139, 1907.
[4]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 45, 1912.
[5]Op. cit., p. 45.
[6]Purdy, R. C., and DeWolf, F. W., Preliminary investigations of Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 139, 1907.

and those which are non-refractory. In other words, the term is used to include those clays which are not fireclays in the strict interpretation of the term. It seems to the writer to be more desirable to use a terminology such as proposed in the classification on pages 10 to 12.

The use of the term No. 3 fireclays seems to be equally unfortunate. These have been described by Purdy[1] as seldom having fusion points exceeding cones 16 and 17. He differentiates them from the No. 2 fireclays on the basis of the rate of temperature-porosity changes. Since the basis of the distinction is not refractoriness and the type clay is non-refractory, it would therefore be better to avoid the use of the word fireclay. There are refractory clays which have a rate of temperature-porosity change which would place them in this group. Because of other physical properties, they are adapted for use for specific purposes which gives them an especial value: for example, the crucible clays and those used for zinc retorts. It would seem a mistake to group this type indiscriminately with the non-refractory clays simply because of the rate of temperature-porosity change.

The method of studying clays by means of the temperature-porosity changes has been found to be exceedingly useful, although the scheme of classification which Mr. Purdy proposed as based upon the rate of these changes has been subject to criticism by later investigators.[2] Some of the difficulties encountered were anticipated by him in the statement "it is possible that broader limits will be determined when more and a larger variety of clays are tested." Beecher[3] in his study of Iowa clays attempted to use the proposed classification but found several marked irregularities. It is difficult to understand these with our present limited knowledge of the mineralogical and chemical constitution of clays. However, it points to the necessity for broader knowledge of these matters. As previously stated, the *method* of study has been widely adopted and has been very fruitful.

PLASTIC REFRACTORY BOND CLAYS

These clays are used in the manufacture of crucibles, glass pots, zinc retorts, and miscellaneous glass house refractories. They are used in mixtures with less plastic clays and with non-plastic materials. According to the investigations of A. V. Bleininger and his associates at the U. S. Bureau of Standards,[4,5] the requirements to be met by these clays are as follows:

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[1]Rolfe, C. W., Purdy, R. C., Talbot, A. N., and Baker, I. O.: Paving brick and paving brick clays of Illinois: Ill. State Geol. Survey Bull. 9, p. 272, 1908.

[2]Bleininger, A. V., The testing of clay refractories: U. S. Bureau of Standards Tech. Paper No. 7, p. 44, 1912.

[3]Beecher, Milton F., Iowa State College Eng. Exp. Station Bull. 40, p. 88, 1915.

[4]Bleininger, A. V., Properties of American bond clays, etc.; U. S. Bureau of Standards, Tech. Paper No. 144, 1920.

[5]Bleininger, A. V., and Schurecht, H. G., Properties of some European plastic fire clays: U. S. Bureau of Standards Tech. Paper No. 79, 1916.

The siliceous clays and those for glass refractories should not soften below cone 30; for severe service the softening point should be above cone 31. In consideration of the clay having other desirable properties, some modification of this may be made; for example, a very well known foreign clay which formerly was widely used softened at about cone 28. The water of plasticity varies between 30 and 45 per cent; the linear drying shrinkage should lie between 6.5 and 10 per cent; the plasticity should be high; the strength as measured in terms of bonding power expressed as modulus of rupture, obtained by testing a mixture of equal parts of the clay and grog is 325 pounds per square inch for Class A, and 225 pounds per square inch for Class B. A classification[1] made according to the burning conduct is as follows:

1—Burn dense at about 1150° C. (2102° F.) and not overfired at 1400° C. (2552° F.). Especially suited for graphite crucibles for brass melting.

2—Burn dense at about 1275° C. (2327° F.) and do not overfire at 1400° C. (2552° F.) or higher. Suited for crucibles for steel and valuable for glass refractories if they do not overburn below 1425° C. (2597° F.).

3—Burn dense at 1425° C. (2597° F.) or higher. May overfire at 1450° C. (2647° F.) or above. Valuable for glass refractories.

4—Burn dense between 1150° C. (2102° F.) and 1300° C. (2372° F.) and have short heat range. Unsuited for refractory bond clay.

The above classification applies to clays burned at the rate of 20° C. (36° F.) per hour above 800° C. (1472° F.).

According to M. G. Babcock[2] the requirements of a zinc retort clay are: Considerable strength and bonding power; a linear shrinkage between 4 and 6.5 per cent; a porosity-temperature range from 10 per cent at 1150° C. (2102° F.) to about 5 per cent at 1250° C. (2282° F.); it should not overburn lower than 1400° C. (2552° F.); deformation point should not be below cone 30.

ARCHITECTURAL TERRA COTTA CLAYS

These are similar to the stoneware clays. They should be free from pyrites, concretions, soluble salts, gypsum, coaly forms of carbon, and other objectionable forms of foreign materials, because the clays are rarely washed before using. The presence of free silica in excess of 3 per cent in the form of grains which will not pass a 200 mesh sieve is considered objectionable by one firm of manufacturers. The red-burning clays are seldom used for this purpose since they are not as well-suited as are the light cream or light

[1]Bleininger, A. V., and Loomis, G. A., The properties of some American bond clays: Trans. of the American Ceramic Soc., Vol. 19, p. 606, 1917.

[2]Babcock, M. G., Refractories for the zinc industry: Jour. Am. Cer. Soc., Vol. 2, p. 81, 1919.

buff colors for the type of decoration ordinarily applied to this product. The clays should have a good plasticity and be strong, but those which are sticky or rubbery when in the plastic condition are avoided. Since the terra cotta bodies are compounded of mixtures of clays and grog (i.e., ground burned clay), the manufacturer may control the shrinkages very readily, but it is desirable that the shrinkages of the clays used should be low or medium. The clays should slake readily when wet with water, so that they may be brought to a uniformly plastic mass without delay. Usually two or more clays are used in the batch. One of these at least should burn dense at some temperature within the ordinary range, namely, between cones 1 and 6, and the minimum porosity should be 10 per cent or lower. The clay should have a sufficiently long heat range at the cone temperature of minimum porosity so that there will not be any danger of overburning in the commercial kiln. These dense burning clays should not warp or crack in the drying or burning process. The other clay used will be of the open burning type.

STONEWARE CLAYS

These are sedimentary clays which have good plasticity and strength, burn to a cream or light tan color, and reach a low porosity between cones 5 and 9. They should be free from substances which will give rise to the formation of soluble salts. It is desirable that the clays be free from concretions, pyrites, coaly forms of carbon, and other substances which may interfere with the use of the clay, although washing of the clay, which is frequently resorted to preparatory to use, will remove them. A comparison of the data regarding the stoneware clays used in different parts of the United States indicates that the physical properties are, on the average, as follows: The water of plasticity is from 18 to 37 per cent, though the usual amount is 35 per cent; the drying shrinkage varies between 5 and 13 per cent, and the average is about 8 per cent; the strength of the clay as measured by the crossbreaking test[1] varies between 125 and 400 pounds with the average at about 250 pounds per square inch; the tensile strength varies between 100 and 300 pounds with an average of 150 pounds; the minimum porosity attained during burning is between 5 and 10 per cent, which may be reached between cones 5 and 10; the average burning shrinkage is probably about 8 per cent.

SAGGAR CLAYS

Two types of clays are used in mixtures for the manufacture of these wares, namely, an open burning clay of good refractoriness, and a clay of lower refractoriness which will burn dense at a low temperature. It is desirable that both types should have good plasticity and good strength, although these properties may be the characteristics of only one of the clays used. It is important that the clays do not contain pyrites, concretionary

[1] I. e., modulus of rupture.

matter, or other foreign material which may cause damage to the wares placed in the saggars for burning. The shrinkages of the clays are not important since the mixtures contain a very considerable amount of grog and, moreover, small variations in size are of no moment. Unless the saggars are to be used at very high temperatures, it is not necessary to use high grade refractory clays. It is quite essential, however, that the clays should be suitable for use in mixtures which are subjected to heavy loads at high temperatures. Knowledge of the fundamentals of good saggar making is as yet in a rudimentary stage, and there is a great divergence in the practice of potters in the choice of materials and their proportions.

SANITARY WARE CLAYS

The clays used in the manufacture of such wares as bath tubs, wash trays, and sinks, are similar to those used in the manufacture of terra cotta.

PAVING BRICK CLAYS

The requirements to be met by these clays are good plasticity so that they may be formed as brick by the auger machine; little or no tendency to laminate; good strength; safe drying properties so that they will not warp or crack during that process; a low carbon and sulphur content so that they may be readily and safely oxidized during the burning process; little or no concretionary material; the color of the burned ware should be a good red in order to meet the usual requirements of the trade, although paving bricks are made also of clays burning to a light color; the minimum porosity should be approximately 5 per cent or less and this should be attained with a sufficiently wide heat range so that there will be no danger of overburning in the ordinary commercial kiln; the product must develop a sufficient degree of toughness to meet the usual tests; the linear drying shrinkage may vary considerably, but the ordinary maximum is 8 per cent and the average is 6 per cent; the water of plasticity of typical paving brick clays is 17 per cent.

FACE BRICK CLAYS

Clays of a great variety are used for this purpose and the requirements which must be met may be stated only in a general way. For the purpose of manufacturing by the plastic process, which is that most generally used, the clay must be of a sort which will flow readily through the die of the brick machine. No marked development of lamination should occur. The clay should have a fair or good strength in the dry condition. It should dry readily and safely without a tendency to warp or crack. The usual shrinkage is from 6 to 8 per cent, although it varies widely. The appearance of a scum, whitewash, or efflorescence of any kind at this or subsequent stages in the manufacture is objectionable. The clay should be practically free from minerals of a harmful kind, size, or quantity, as for example, calcium carbonate in its various forms, pyrites, and concretionary iron. The clays should burn hard and strong without warping, blistering, pitting, etc.

They should attain a low per cent of absorption at a temperature which is commercially practicable. This varies widely according to the type of material and may be said not to exceed cone 8 and usually lies below cone 1. The clays should have a sufficiently wide heat range to permit the necessary degree of vitrification without danger of overburning and the variations in color throughout the burn should be of a sort both as to shade and variety as to permit satisfactory grading.

Conservation of Clays

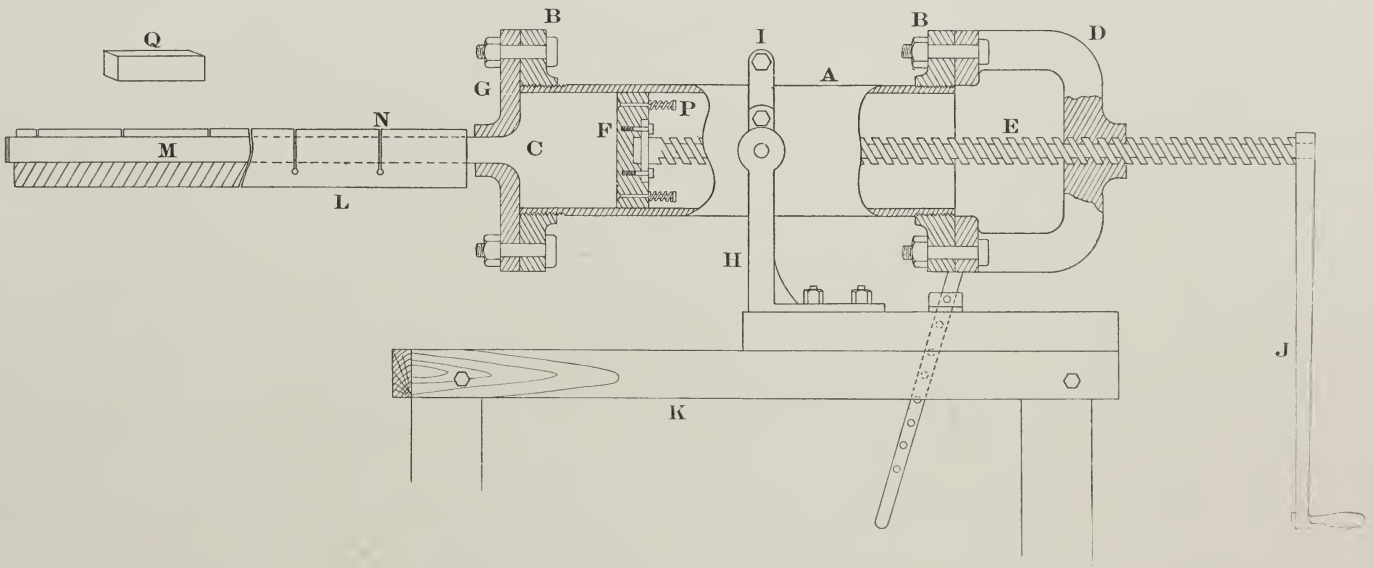
We have been accustomed to regard the supply of our better grades of clays as practically inexhaustible. Considering the great area of the whole country and the large portion still unexplored economically, this may be accepted as true. However, in those states which are most largely given over to industrial pursuits, it is scarcely wise to make this assumption. While it is true that we have large areas with great tonnages in the process of utilization and other areas known and unknown yet to be exploited, still we should not evade the fact that in some important districts the end is in sight. It is wise, therefore, to have in mind the importance of conserving the supply of the better grades of clays. This may be done by obtaining a complete knowledge of the extent and character of our clay resources; by a more precise knowledge of the requirements of the raw materials for the manufacture of the various wares; by less wasteful methods of mining; by the use of methods of purification to render clays serviceable which would otherwise be unavailable for use; by the adoption of the practice of blending clays from certain areas or districts so that there would be a more complete utilization of the output from small mines of the region or of certain strata of clays; by the avoidance of the practice of using superior material, either the raw material or the finished product, where an inferior grade would suffice.

As an instance of the importance of a more adequate knowledge of our clay resources, we may cite the diaspore deposits of Missouri. For many years flint clay deposits in certain counties of that state have been operated. A peculiar rough type of clay found in those pits was regarded as detrimental or worthless, and abandoned pits may be found today where large bodies of it were left. Within the past three years, this material has been found to be of exceptional interest and value because of the extraordinarily high content of alumina.[1]

The Physical Properties and the Methods of Testing the Clays

The methods of testing employed were, with few exceptions, those recommended tentatively by the American Ceramic Society's Committee on Standards in its report of 1918.

[1]Buehler, H. A., Biennial Report of the State Geologist of Missouri, p. 18, 1919.



A 5-inch standard pipe, machined	E Square tread screw	I Strap	M Clay Column
B Pipe flanges	F Piston plate	J Crank	N Cutting slots
C Clay	G Die	K Table	P Pin and spring
D Yoke	H Stand	L Cutting box	Q Briquet as cut, 1″x1″x3½″

FIG. 44. Hand plunger machine for molding briquets.

PRELIMINARY PREPARATION

The quantity of each sample collected by the field geologist and sent to the laboratory approximated fifty pounds weight, but was less when special circumstances made a smaller amount necessary, as in the case of samples gathered by boring with an auger.

After a careful inspection of the dried material, in which observations were made as to its general character, its degree of homogeneity, and the presence of easily distinguishable minerals, organic matter, and other impurities, the sample was crushed by passing through a set of rolls excluding, of course, any pebbles or lumps of an obviously foreign nature. The occurrence of pebbles or foreign material was quite unusual. This crushing operation was limited strictly to the breaking down of the larger lumps of clay and no grinding was done.

The powdered clay was passed through a twenty-mesh sieve, and the fines were moistened with a sufficient quantity of water to permit the working of the mass into a plastic condition of the right consistency to be molded into the test pieces. The determination of the correct consistency was dependent upon the judgment of the operator. Sometimes a few trials were necessary in order to arrive at the proper condition. Since plastic clays are workable with a fairly wide range of water content, it will be noted in the reports upon the tests of clays that in some instances a certain amount of variation occurs with the same clay. Thorough kneading or wedging, as it is called, was employed in order to insure a uniformity in the mass.

THE TEST PIECES

FORMATION

The pieces required for the testing were formed by one or the other of two methods. The method ordinarily used was to place the plastic mass in the barrel of a piston press and to force the clay to flow out through a die having an opening one inch square. The bar of clay thus formed was cut into pieces about four inches long.

This apparatus (see Fig. 44) is the same one as described and used in the "Tests on Clay Materials Available in Illinois Coal Mines," published by the Illinois State Geological Survey as Bulletin 18 of the Coöperative Mining Investigations series.

This method furnished also a means for estimating the relative ease or difficulty with which a clay would flow through a die, a factor which is of importance in some lines of manufacture.

The alternative method was to form a roll of clay of the approximate dimensions of a small brass mold and to tamp the roll into the mold, taking care to have it filled completely. The piece thus formed was of the same size as that formed by squeezing through the die.

DRYING

The test pieces were dried carefully by keeping them for a period of several hours at the room temperature, then in a drier at a temperature of 100° F., and finally at a temperature of 212° F.

RAW CLAYS: THEIR PROPERTIES AND METHODS OF TESTING

SHRINKAGE

Shrinkage is the contraction which takes place in a clay during the drying or the burning of the same. In the former case, it is due to the loss of the water which has been introduced to render it plastic and which surrounds and separates the particles. The amount of the shrinkage varies widely and may be classified[1] as follows:

	Per cent
Low	0 —3
Medium Low	3.1—6
Medium	6.1—9
Medium High	9.1—12
High	12.1 and upwards

Excessive shrinkage will render a clay unfit for use for many purposes and often causes warping or cracking.

Linear.—Immediately after forming each piece, it was marked for identification and shrinkage marks were made upon one face spaced 3⅛ inches apart. After the completion of the drying, the pieces were again measured in order to determine the amount of linear shrinkage, which was calculated as follows:

$$\text{Percentage of Linear Shrinkage} = \frac{\text{Length of plastic piece} - \text{Length of dry piece}}{\text{Length of dry piece}} \times 100$$

In many cases the linear shrinkage is also expressed in terms of the plastic length, as for example:

$$\text{Percentage of Linear Shrinkage} = \frac{\text{Length of plastic piece} - \text{Length of dry piece}}{\text{Length of plastic piece}} \times 100$$

Volume.—The determination of the volume shrinkage was made in many cases. It was done by means of a volumeter which is described later (see page 29). The results were calculated as follows:

$$\text{Percentage of Volume Shrinkage} = \frac{\text{Volume of plastic piece} - \text{Volume of dry piece}}{\text{Volume of dry piece}} \times 100$$

The method used is more refined than that employed for linear shrinkage and consequently the results are more accurate.

[1] A slightly modified form of the classification given by: Watts, A. S., Classification of clays on a ceramic basis: Jour. Am. Cer. Soc., Vol. 3, p. 247, 1920.

WATER OF PLASTICITY

The amount of water required for addition to a clay to render it readily workable is known as the "Water of Plasticity." It varies widely in different clays, depending upon the fineness of grain and relative amount and character of the colloidal content. It varies also with the same clay. In general, the more plastic clays have the larger content of water of plasticity and exhibit the widest variations in amounts for the individual clays. They also show the greatest strength in the dried state. The following table[1] shows the water of plasticity content of some typical clays and shales:

	Per cent	
Galesburg Shale	26.7	Good working properties
English Ball Clay M. and M. No. 1	49.3	Very plastic, rather sticky
Tennessee Ball Clay No. 3	52.5	Very plastic, rather sticky
English China Clay	44.1	Fairly plastic
Georgia Kaolin	26.2	Very plastic, rather sticky
Florida Kaolin	45.2	Good plasticity, rather sticky
North Carolina Kaolin	34.2	Slightly plastic, sticky

The calculation of the water of plasticity was made as follows:

$$\text{Percentage of Water of Plasticity} = 100 \times \frac{\text{Weight of plastic clay} - \text{Weight of clay dried at 212° F.}}{\text{Weight of clay dried at 212° F.}}$$

The water of plasticity consists[2] of the "Shrinkage Water" which is that part which is driven off during the drying period up to the time when shrinkage ceases; and the "Pore Water" or that portion which still remains when shrinkage ceases, retained in the pores of the piece until the completion of the drying has driven it all out.

Shrinkage water.—The shrinkage water was determined by measuring the volume of the test piece before and after shrinkage ceased and reporting the difference in terms of percentage of the dry weight; as, for example:

$$\text{Percentage of Shrinkage Water} = \frac{\text{Plastic volume} - \text{Dry volume}}{\text{Dry weight}} \times 100$$

Pore water.—Since the pore water is the portion of the water of plasticity retained in the pores after shrinkage ceases, it is therefore calculated as follows:

$$\text{Percentage of Pore Water} = \text{Percentage of Water of Plasticity} - \text{Percentage of Shrinkage Water}$$

Clays in which the ratio of shrinkage water to the pore water is high are likely to have excessive or sticky plasticity and to warp or crack in drying. This ratio undoubtedly bears an important relation to the strength of the unburned clay. These properties are dependent also upon other factors such as the shape and the relative proportion of the various sizes of non-plastics in the mass so that in our present state of knowledge a correlation cannot

[1] Kinnison, C. S. A study of the Atterberg plasticity method: U. S. Bureau of Standards Tech. Paper No. 46, pp. 11-12, 1915.

[2] No account is taken here of the hygroscopic water, imbibed or absorbed water.

be made. However, according to certain investigations by A. V. Bleininger[1] the best clays for glass pots and crucibles have a pore water-shrinkage ratio of 1:1.

FINENESS

The relative proportions of the non-plastic material of various sizes present in clays varies within wide limits and the choice of a clay for special purposes sometimes depends upon a particular amount or size. For example, the use of siliceous clays in the mixture for glass pots has been found of distinct advantage.

It is desirable, therefore, to have such information available and it would be of advantage to have more information about the mineral character and the physical form of the non-plastic particles.

Plasticity, drying conduct, drying shrinkage, strength and burning properties are all largely influenced by the non-plastics. In some cases the removal of non-plastics above a certain size is necessary as in the case of the manufacture of stoneware.

One hundred grams of the dried sample were shaken with 800 cc. of water in a mechanical shaker until the mass was thoroughly disintegrated. The mixture was then poured on to a set of sieves of the meshes recorded in the tests. The soft lumps of the residues were crushed by rubbing with the fingers and washed thoroughly, dried and weighed. The results are reported in the terms of the total weight of the dry clay used.

In the reports on the results of tests which follow, the classification given herewith is used:

Amount of residue *Per cent*	
0—3.5	Slight
3.6—5.5	Low
5.6—10.5	Moderate
10.6—25.5	Considerable
More than 25.5	High

SLAKING

The slaking test has been recommended as preliminary test of especial service in distinguishing between clays of high and low strength. Many clays which require thirty minutes or more to slake have high tensile and transverse breaking strength in the unburned condition. Clays which slake quickly have low or medium strength. This test is useful for a rough approximation only which should be confirmed by the usual strength tests.

An intimate mixture of equal parts of dry clay and potter's flint was moistened with water and after working to a plastic condition was shaped as a bar measuring 4 in. by 1 in. by 1 in. This bar was cut into cubes

[1]Bleininger, A. V., Properties of American bond clays, etc.: U. S. Bureau of Standards Tech. Paper No. 144, p. 51, 1920.

approximately one inch on each side. After carefully drying these, first at room temperature, then at 160°-170° F., and finally at 212° F., they were cooled, placed on wire mesh trays (four meshes to the inch), and then submerged in water at room temperature. The cubes slaked more or less slowly and the time required for this to be completed was noted. Care was taken to avoid agitation of the water during the slaking process.

TRANSVERSE STRENGTH

The strength of dried unburned clay is determined either in terms of tensile strength or the cross-breaking strength. The latter is more commonly used by American ceramists at present because of the simplicity of the apparatus and the greater uniformity of results obtained. A modulus of rupture of less than 200 pounds per square inch may be regarded as low; between 200 and 400 pounds per square inch as good; and above 400 pounds as high. This test is of use in the valuation of all clays but especially those which are be used alone or with other clays, and without the addition of non-plastics as such. The washing of the clay may or may not impair its strength.

Test bars 6 in. by 1 in. by 1 in. were formed according to the methods previously described, dried first at room temperature, then at 140° to 150° F. for 24 hours, and finally at 212° to 220° F. for 24 hours. After removal from the oven, and cooling to room temperature, the pieces were then supported upon knife edges placed five inches apart. At a point midway between the supports rested the knife edge of a yoke from which hung a pail. A stream of sand was fed into this pail until the weight was sufficient to break the bar.

The result of the test was recorded as the modulus of rupture which was calculated as follows:

$$\text{Modulus of Rupture} = \frac{3 \times \text{Weight in pounds} \times \text{Distance between supports}}{2 \times \text{Breadth} \times \text{Depth}^2}$$

Twenty pieces were tested in all cases where sufficient material was at hand. The final result reported was the average of all the values which did not vary more than 25 per cent of the maximum.

The "modulus of rupture" classification used in describing the results of tests of transverse strength is the same as that given below for bonding strength.

BONDING STRENGTH

It is the practice in the manufacture of many kinds of wares to use more or less non-plastic material containing particles of varying size and shape, as, for example, in furnace blocks, fire brick, crucibles, glass pots, abrasive wheels, architectural terra cotta, and zinc retorts. For such uses, it is highly important that the clays used should permit such admixtures

with a retention of maximum strength. Ordinarily the addition of considerable amounts of non-plastics results in a decrease in the cross-breaking strength as compared with that of the pure clay. In some instances there is little change and sometimes an increase. The following classification proposed by Professor A. S. Watts,[1] slightly modified, has been employed:

Modulus of Rupture

	Lbs. per sq. in.
Low	0—100
Medium Low	101—200
Medium	201—400
Medium High	401—800
High	801 and above

Equal parts of clay and standard sand[2] were brought to a plastic condition by the addition of water and thorough wedging. Test pieces were formed from this mixture. The method of preparation, the size, the conditions of drying and mode of breaking were similar to those described under "Transverse Strength."

The results are reported in terms of the modulus of rupture, which is calculated in the manner already described.

BURNED CLAYS: THEIR PROPERTIES AND METHODS OF TESTING

PYROMETRIC METHODS USED

The test pieces prepared for the determination of the drying shrinkage were burned in a coal-fired laboratory test kiln of the down draft type, having a chamber capacity of approximately 27 cubic feet. The normal rate of firing was:

From room temperature to 572° F.	9 hours
From 572° F. to 1112° F.	6 hours
From 1112° F. to 1382° F.	12 hours
From 1382° F. to 1850° F.	7 hours
From 1850° F. to finish	45°—54° F. per hour

Ordinarily, the trial pieces were placed in closed saggars to protect them from the flames and dust carried by the draught through the kiln.

A separate burn was made for each of the several pyrometric cones indicated in the reports on the tests, excepting as it became desirable in some cases to set the kiln so that test pieces could be drawn from time to time as the desired cone-temperature was reached.

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[1]Watts, A. S., Classification of clays on a ceramic basis: Jour. Am. Cer. Soc. Vol. 3, p. 247, 1920.

[2]Standard sand is prepared especially for use in the testing of cement. It is sized to pass a twenty-mesh sieve (0.0328-inch hole, 0.0172-inch wire) and is retained on a twenty-eight mesh (0.0232-inch hole, 0.0125-inch wire).

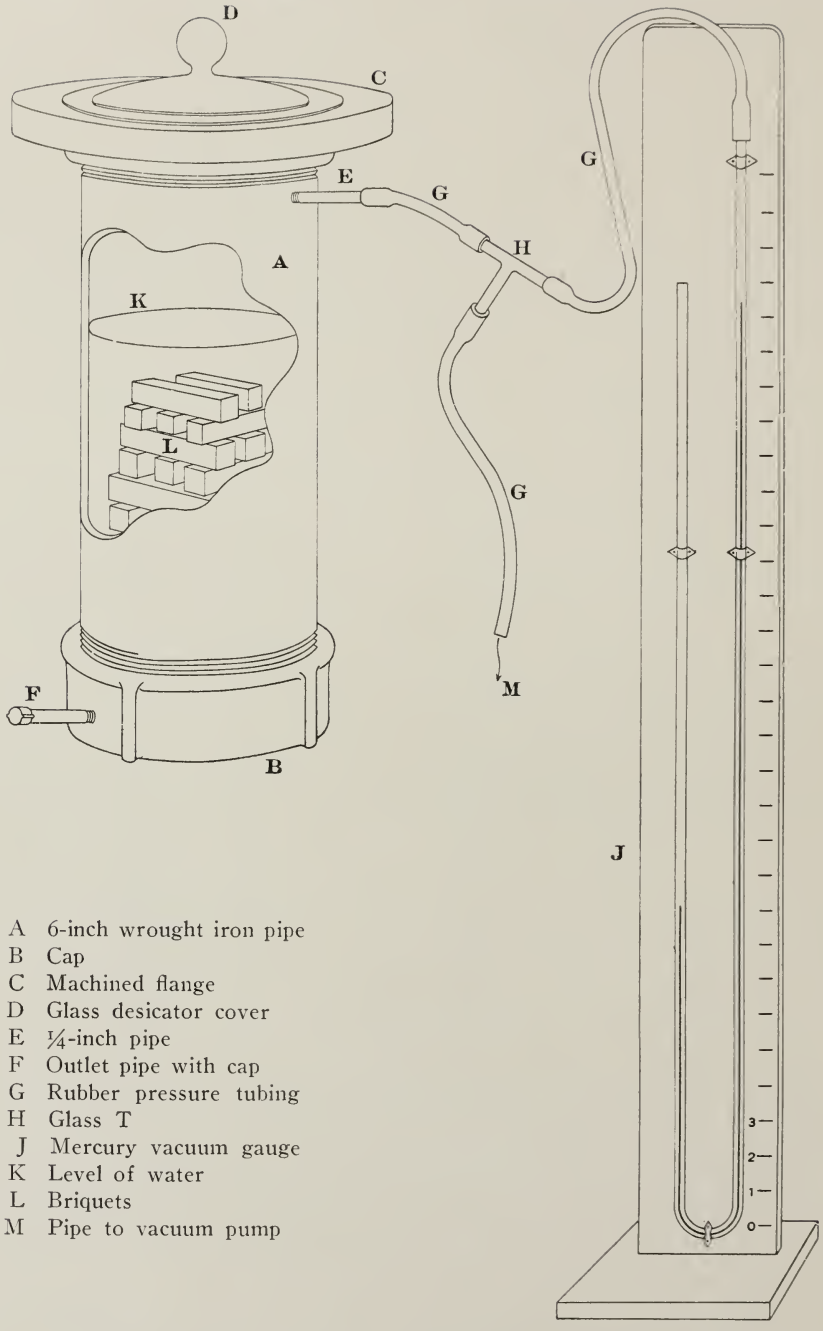
The pyrometric cones used were those made by Professor Edward Orton, Jr., of Columbus, Ohio. With respect to the temperature equivalents of these cones, it should be borne in mind that the pyrometric cone is a measure of the effect of the time-temperature relation as has been repeatedly pointed out but often disregarded. Therefore, the temperature at which a cone "goes down" is dependent upon the rate of firing. This has been carefully investigated by the Bureau of Standards and is discussed in a paper on "The Function of Time in the Vitrification of Clays," published as Technologic Paper No. 17. In the following table, a comparison is made of the cone-temperature scale: Scale (a) is as usually given, and scale (b) is as reported in the paper referred to when the rate of heating was at 49.5° F. per hour, which is nearly that used in these burns.

COMPARISON OF TWO CONE-TEMPERATURE SCALES

Cone	(a) Usual Scale	(b) Rate = 27½° C. per hour	
	Deg. F.	*Deg. C.*	*Deg. F.*
010	1742	885	1625
09	1778	930	1706
08	1814	970	1778
07	1850	975	1787
06	1886	1000	1832
05	1922	1035	1895
04	1958	1055	1931
03	1994	1065	1949
02	2030	1070	1958
01	2066	1080	1976
1	2102	1085	1985
2	2138	1090	1994
3	2174	1110	2030
4	2210	1125	2057
5	2246	1135	2075
6	2282	1140	2084
7	2318	1155	2111
8	2354	1170	2138
9	2359	1190	2174

A thermo-electric pyrometer was used in each burn in order to determine the rate of increase of temperature. It was thought impracticable to rely solely upon the pyrometer in finishing the burns because of the impossibility of grouping the test pieces within or without the saggars close enough to the thermocouple to insure certainty regarding the uniformity of the temperature distribution, whereas the cones could be scattered throughout the kiln where needed.

Two pieces were burned at each temperature indicated in practically every case, and an average taken of the results obtained.



A 6-inch wrought iron pipe
B Cap
C Machined flange
D Glass desicator cover
E ¼-inch pipe
F Outlet pipe with cap
G Rubber pressure tubing
H Glass T
J Mercury vacuum gauge
K Level of water
L Briquets
M Pipe to vacuum pump

FIG. 45. Apparatus for saturating briquets in vacuo.

BURNING SHRINKAGE

The shrinkage resulting from burning is the contraction due to the loss of water and other volatile matter, a certain amount of condensation of the components, and the softening of the mass with the consequent closing up of the voids by the more fluid portions. A high shrinkage may lead to cracking or warping of the piece and is avoided therefore in the manufacture of all ware of complicated form or large size. The following classification proposed by Professor A. S. Watts, slightly modified, is presented for comparison:

Total Shrinkage at Cone 10

	Per cent
Low	0 — 4
Medium Low	4.1— 8
Medium	8.1—12
Medium High	12.1—16
High	16 and above

In the "Results of tests" included in this report, the term "Burning shrinkage" means linear burning shrinkage in every case.

POROSITY

Porosity is the ratio between the volume of the pores and the volume of the whole piece. The volume of the pores was determined by saturating the piece with water in vacuo (see Fig. 45) and noting the weight of the water absorbed. The volume of the piece thus saturated was obtained by measuring the amount of displacement caused by its introduction into a modified form of the Seger volumeter. This apparatus consists of a large-size glass bottle with a wide neck covered by a glass cap ground to fit snugly. To the side of this bottle is connected a burrette or graduated glass tube, which permits a reading of any change of volume of the contents of the large bottle. The per cent porosity is calculated as follows:

Saturated weight − dry weight = weight of water absorbed
Weight of water absorbed gives volume of water absorbed
Volume of water absorbed = volume of pores

$$\frac{\text{Volume of pores}}{\text{Volume of test piece (including pores)}} \times 100 = \text{Percentage of Porosity}$$

COLOR

The color changes at the various cones were noted.

FUSION, OR DEFORMATION TESTS

The fusion or deformation tests were made in a Fletcher furnace for the lower temperatures and in a Deville furnace for the more refractory materials. The latter is operated by placing the test pieces in a crucible, surrounding them with coke, and forcing the combustion with a low pres-

sure air blast. The test pieces were molded into the form of four-sided pyramids measuring 0.23 inches along each edge of the base and 1.2 inches high. Standard pyrometric cones made by Professor Edward Orton, Jr., were placed in the furnace with the test pieces to serve as indicators of the cone temperatures reached.

In the reports of the results of tests, clays which deform below cone 27 are termed *non-refractory,* those which deform between cones 27 and 31 inclusive, *refractory,* and those which deform at cone 33 and above, *highly refractory.*

DISTRIBUTION OF ILLINOIS CLAYS

By C. R. Schroyer

Refractory clay is restricted in Illinois to the basal part of the Pennsylvanian ("Upper Coal Measures") and to the younger embayment deposits of Cretaceous-Tertiary age. A few local developments are associated with other horizons, usually as residuals above limestones, but such occurrences are rare and not of great importance. The clays will be discussed in order, as: (1) Clays of the embayment area, (2) Clays of Pennsylvanian age.

Geographically the refractory clays of Illinois are to be found (1) in the extreme southern counties; (2) in a narrow zone extending from East St. Louis to Rock Island; and (3) locally along Illinois River in LaSalle and Grundy counties. Fig. 43 indicates the general distribution of refractory clays.

The southern clays are part of the younger embayment deposits and are found in Pope, Massac, Pulaski, Alexander, Union, and Johnson counties. The "pocket" deposits near Mountain Glen, Union County, are the most important and have furnished the highest grade clay. Others of a similar nature are found near Grand Chain, Pulaski County. In the counties adjoining Ohio River, bedded clay is widely distributed but is not always of a quality desirable for commercial purposes. Figure 46 shows the embayment deposits.

The zone extending from East St. Louis to Rock Island (see Fig. 43) includes parts of St. Clair, Madison, Calhoun, Greene, Pike, Scott, Adams, Brown, Schuyler, McDonough, Fulton, Warren, Mercer, Rock Island, and Henry counties. While clay is quite generally present at the Cheltenham horizon throughout this entire belt, it is only locally of commercial value, as at Alton, Madison County, Alsey, Scott County, Colchester and Macomb, McDonough County, and Rock Island, Rock Island County.

In La Salle and Grundy counties at the base of the Pennsylvanian there is also a clay of refractory value. Pits are worked near Utica and Ottawa, and mines near Oglesby and Marseilles. In the vicinity of Goose Lake, Grundy County, there is a partially developed deposit which contains lenses of a semi-flint type of clay.

A report by Stuart St. Clair gives in some detail a discussion of the Union County clays.[1] E. H. Lines has studied the stratigraphy of the Cheltenham clay of Illinois.[2] As those publications are still available, only such of the matter of those reports will be repeated as is necessary for clearness.

In the introduction a general discussion has been made of the classification of clays, their properties and uses, and methods of testing. For a discussion of the character and origin of clays, the reader is referred to Bulletin 9[3] of the Survey.

CLAYS OF THE EMBAYMENT AREA

Long after the Pennsylvanian ("Coal Measures") shales, limestones, sandstones, and coals had been deposited, and after the surface of these formations had been weathered and eroded, the level of the sea relative to the land changed so that a wide open bay extended from the Gulf of Mexico northward into southern Illinois. Debris carried into this basin from the bordering land formed interstratified beds of sand, silt and clay, which make up the embayment deposits (see fig. 46) and include the refractory clays of southern Illinois.

Paleozoic Floor and Border

Beds of Paleozoic age border the embayment deposits on the outer rim and presumably form the floor of the entire basin. Their decayed products have been the source of the younger sediments. In Illinois these Paleozoic rocks are of Mississippian and Devonian age. The Mississippian beds forming most of the eastern and northern border are cherty limestone and shale with minor horizons of sandstone. The high bluff of a former channel of Ohio River roughly parallels embayment deposits on the north and rises at New Columbia to a height of 150 feet above them. Erosion has exposed Mississippian beds in southwestern Pope, central Massac, and Pulaski counties south of this channel, either as highland inliers or as bordering fringes at the north of the embayment deposits.

In Alexander and Union counties older beds of Devonian age border the embayment area and form the highlands of southwestern Illinois. These cherts and decayed siliceous rocks overlie Alexandrian and Ordovician limestones which outcrop in the bluffs of the Mississippi River flood-plain.

Correlation and Division of the Embayment Deposits

From certain features common to the embayment deposits and other beds elsewhere, and from the continuity of connection at the south as well as from an occasional fossil, these beds are known to be of Cretaceous and

[1]St. Clair, Stuart, Clay deposits near Mountain Glen, Union County, Illinois: Ill. State Geol. Survey Bull. 36, pp. 71-83, 1920.

[2]Lines, Edwin H., Pennsylvanian fireclays of Illinois: Ill. State Geol. Survey Bull. 30, pp. 61-73, 1917.

[3]Rolfe, C. W., Geology of clays (part of paving brick and paving brick clays of Illinois): Ill. State Geol. Survey Bull. 9, pp. 1-46, 1908.

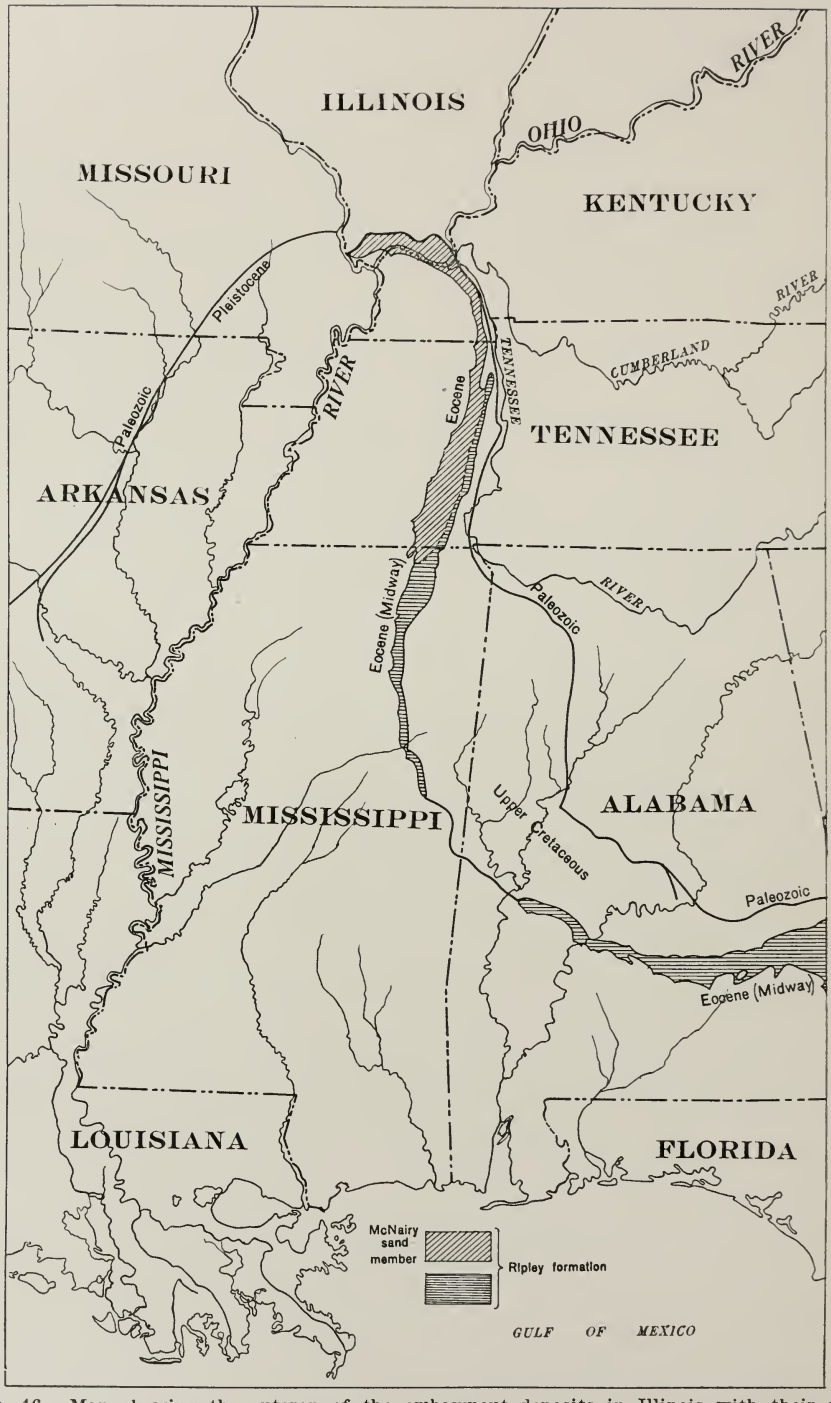


FIG. 46. Map showing the outcrop of the embayment deposits in Illinois with their relationships to similar deposits farther south. The heavy line labelled "Paleozoic" which swings north from Arkansas into Illinois and thence south into Alabama, is the boundary of the deposits laid down in the embayment which extended northward from the Gulf in Cretaceous and Tertiary times. Only the outcrop of the Ripley formation is shown. South of the Ripley in Illinois Eocene and younger formations are uppermost, and remnants of these younger formations are found even in and perhaps beyond the area mapped as Ripley. *(After Stephenson.)*

Tertiary age. In the states farther south, where there are definite breaks between formations, it has been possible to draw lines that definitly subdivide these deposits, as indicated in the accompanying table. In Illinois, however, with only the outer margins present it is difficult and in some cases probably impossible to separate them into distinct horizons.

Each formation listed in Table 1 represents a transgression of the sea and each break represents a period of erosion. How far north these beds extended or how thick they were originally can not be determined from their present distribution. Small outliers are found far beyond the areas of connected strata. For example, at New Columbia, Massac County, and south along the bluff such remnants are found both as terraces and as thin beds over the Paleozoic uplands, 150 feet or more above the present valley level, as indicated by the fact that a well on the bluff southeast of New Columbia 18 feet deep ended in red sand by a section of the road from the levee to the top of the bluff at this place:

Section of bluff at New Columbia

		Thickness *Ft.*	*In.*	
9.	Loess	10	..	
8.	Gravel	..	6	
7.	Sandstone, platy, red and gray	6	6	
6.	Sandy beds, light in color	10	8	
5.	Sandstone, shaly; weathers to 3-inch beds	6	..	
4.	Clay shales, sandy, white and buff interbedded	7	6	
3.	Clay, sandy, white with iron-colored streaks	3	..	
2.	Partly covered	5	..	
1.	Sandstone (Mississippian)	100		(Bar.)

A section measured near Rosebud gives similar indications:

Section 2 miles south of Rosebud, Pope County, in the SE. ¼ sec. 33, T. 14 S., R. 6 E.

		Thickness *Feet*	
6.	Gravel	2±	
5.	Clay, light colored, sandy, and thin beds cemented by iron	16	
4.	Shales, buff and gray, sandy; thin compact irony beds near the top.	6½	
3.	Sandy beds, partly covered, variegated, micaceous	22	
2.	Covered	40	(Bar.)
1.	Limestone (Mississippian)	25	

This bluff rises 150 feet above the level of the present alluvial deposits and the capping suggests that it has been completely buried by a filling of sand and clay.

Near Vienna, Johnson County, small terrace remnants of bluish white stratified clay shale interbedded with hard red, sandy beds also suggests the former presence of more extensive deposits. Such small remnants are

TABLE 1. *Subdivisions of the embayment deposits, recognized by various authors*

Description of Horizon	Approximate Thickness	From Professional Papers [a] 81, 90J, 95F, 120C, and 120H		From Water-Supply Paper 164[b]	System	Relations In Illinois
	Feet	*Formations*		*Formations*		
Sands with clay lenses and greensand. Characteristic life remains	200±	Jackson			Tertiary (Eocene)	
		(Erosion interval)		——?——		
Highly fossiliferous greensands not recognized outside of the Alabama area	30 to 40	Gosport	Claiborne 450±			Not represented in Illinois
Calcareous, argillaceous, and glauconitic fossiliferous sands	100 to 150	Lisbon				
Siliceous claystone, calcareous and fossiliferous toward the east	200±	Tallahatta				
		(Erosion interval)				
Laminated, sandy clays and cross-bedded, calcareous sands carrying fossils and some greensand	175	Hatchetigbee	Wilcox 850±	Lagrange		Represented in Illinois. The high grade clays of Mountain Glen, Grand Chain and possibly Raum, questionably referred to this horizon. Continuous deposits cover a triangular area in the extreme southern part of State
Sandy clays and thick lenses of calcareous glauconitic sands. A bed of lignite at the base	?	Bashi				
Gray and yellowish cross-bedded sands and sandy clays, massive below and laminated above	140	Tuscahoma				
Sandy glauconitic beds alternating with grayish, calcareous clays. Lignite bed at base	200	Nanafalia				
		(Erosion interval)				
Lignitic ferruginous sandy clays and beds of lignite or coarse micaceous, highly colored sands with micaceous clays. Greensand	?	Naheola Sucarnochee	Midway	Porters Creek		Probably present, but no distinctive marks of identification
		Clayton (Distinct erosion interval and faunal change)				
Sands usually light in color, but with considerable variation; pink light yellowish, brown, and locally also leaden or slate colored clay, 10 to 20 or more feet thick. Iron concretions characteristic. Calcareous and glauconitic beds	250 to 300	(Thought to be of the same age as the Selma farther south)		Ripley (McNairy sand member at the north)	Cretaceous	Extends as a curved belt 5 to 15 miles wide about the outer margin of the embayment deposits. Known from deep excavation at Cairo
Clay of a light leaden gray or greenish color when dry; somewhat darker when wet. Greensand present in some layers. Calcareous shells at the south	950			Selma		Absent
Sands which locally contain calcium carbonate and greensand	450			Eutaw		
Sands and clays of shallow water origin	1000±			Tuscaloosa		
		(Distinct break)				
		Paleozoic formations				

[a]–Stephenson, L. W., Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, 1914.

Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf coastal plain: U. S. Geol. Survey Prof. Paper 90J, 1915.

Berry, E. W., Erosion intervals in the Eocene of the Mississippi embayment: U. S. Geol. Survey Prof. Paper 95F, 1915.

Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120C, 1918.

Stephenson, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geol. Survey Prof. Paper 120H, 1918.

[b]–Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U. S. Geol. Survey Water-Supply and Irrigation Paper No. 164, 1906.

known in the Devonian area of Alexander and Union counties as far north as Mountain Glen, and the deposits of refractory clay at that place are probably outliers. Still farther north clay has been dug at an elevation of about 625 feet above sea level, northwest of Alto Pass near the north line of Union County. Outliers of sand and thin-bedded clays are found west of Pomona in Jackson County at an elevation of about 650 feet above sea level. This clay is so white that it has been used by the farmers for white wash and paint.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

RIPLEY FORMATION

The four lower embayment formations listed in the table are of Cretaceous age but only the highest of these, the Ripley formation, extends into Illinois. The northern extension of this formation is composed largely of loose sands and sandstone, and is known as the McNairy sand member. The McNairy extends in a curved belt across southwestern Pope, southern Massac, and central Pulaski counties, and in a constricted narrow belt across Alexander County, terminating not far from Fayville at Mississippi River. The width of this belt varies from 10 miles north of Metropolis to less than half that width in central Alexander County. Younger beds of Tertiary and Quaternary age overlie most of this area.

Lithologic Character.—In Tennessee the Ripley formation is composed mostly of stratified, variegated sands, that are commonly rich in iron and contain "pipes" and irony masses. "The sands are usually fine gravel and between them are found beds of gray lignite or yellow sandy micaceous clay."[1] Drying cracks now filled with limonite indicate periods of exposure early in the history of the deposit.

In Kentucky the Ripley is a "black clay in very thin laminae, separated by fine white and highly micaceous sand; beds of sharp angular white and yellow micaceous sand 100 feet thick."[2]

In Illinois the fewness of Ripley exposures makes study of this horizon difficult. In general, however, the formation is made up of variegated sands interstratified with beds of gray, leaden, or slate-colored clay, 10 to 20 feet or more thick. The sands are commonly rich in iron, and ironstone layers and concretionary masses are abundant. The clays of Massac County are of this age.

Sections of the McNairy sands of the Ripley formation in Illinois follow:

---

[1]Nelson, W. A., Clay deposits of West Tennessee: Geol. Survey of Tennessee Bull. 5, p. 11, 1911.

[2]Gardner, James H., Kentucky Geol. Survey Bull. 6, p. 83, 1905.

Log of the Eichenseer well, one mile below Yates Landing in the SW. ¼ sec. 2, T. 15 S., R. 2 E.

Description of strata	Thickness *Feet*	Depth *Feet*
Loam and loess	18	18
Gravel, coarse	3	21
Sand, white	30	51
"Potters clay," white	6±	57
Sand, white, with small lumps of clay	70	127

Section of east bank of drainage ditch 300 yards north of Ohio River

		Thickness *Ft.*	*In.*
5.	Soil	1	3
4.	Loess	5 to 15	..
3.	Gravel and sand, stained brown or red by iron; compact at base.	1	3
2.	Clay, bluish, micaceous, sandy, with thin lenses of sand	2	6
1.	Sand and clay interbedded and slumped together	8	10

Log of the Stoner well in sec. 28, T. 15 S., R. 6 E.

Description of strata	Thickness *Feet*	Depth *Feet*
Clay and "loam," yellow	10	10
Sand, fine	2½	12½
"Soapstone," dark compact clay, with lignite	9	21½
Sand and clay, red in color; some harder irony layers, others white and buff	28	49½
Rock, hard; bottom of well	..	..

Section half a mile west of Round Knob

		Thickness *Ft.*	*In.*
4.	Gravel; unmeasured	..	..
3.	Clay, red	4	..
2.	Clay, white and pink	6	6
1.	Sand, red and white, case hardened ferruginous layers	18	..

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY FORMATION

The Midway formation includes the oldest beds of Tertiary age, and south of Illinois it rests with marked unconformity on the underlying Cretaceous.

Only in the vicinity of Caledonia Landing east of Olmsted have exposed deposits in Illinois been correlated with the Midway, although in wells at

Cairo and Mound City, beds 100 feet thick have been classified as Porters Creek [Midway].[1]

This phase of the Midway extends westward from Caledonia as a belt a few miles wide.

Lithologic Character.—Sections indicating the character of the Midway, especially its variability, follow:

Section of the Midway formation at Caledonia Landing[2]

		Thickness Feet
8.	Gravel, sand, and shale fragments	5
7.	Shale fragments, light gray; probably "in place"	25
6.	Shale, light gray, lumpy	11
5.	Clay, sandy, greenish gray and seamed by ferruginous clay "dike"	1
4.	Clay shale, dark gray or drab, seamed by ferruginous clay "dike"	6
3.	Shale fragments, light gray	3
2.	Clay shale, brown to black, "fat," lumpy	3
1.	Shale, debris, dark and light gray	2
	Water level	

The section varies from place to place as is evident from the following:

Section of Midway formation a quarter mile upstream from Caledonia Landing

		Thickness Ft.	In.
12.	Gravel, chert pebbles	1±	..
11.	Shale, gray, sandy, small stains of lignite	8	..
10.	Sand, small hollow iron concretions	3	6
9.	Sands and clay, buff and gray, partly covered	5	6
8.	Hematite layer	..	2
7.	Sand	..	6
6.	Iron oxide bed, concretionary, platy	..	4
5.	Sand, gray, micaceous	2	..
4.	Ferruginous bed	..	10
3.	Sand, buff, and iron concretions	1	6
2.	Concretionary ferruginous bed, indistinct fossil casts (?)	..	8
1.	Covered	10 (Bar.)	
	Water level		

The nature of the Midway beds at this place strongly suggests beds of Ripley age.

Less than a quarter mile below Caledonia Landing, a solid bank of 55 feet of dark shale, almost black when wet, but light gray when dry, rises above the water level. Upon drying it cracks out in characteristically large, roughly angular blocks. This deposit is the "soapstone" of the Midway group.

[1]Purdy, Ross C., and DeWolf, Frank W., Ill. State Geol. Survey Bull. 4, p. 143, 1907.
[2]Op. cit., p. 144.

Section of Chalk Bank 2½ miles above Caledonia

		Thickness Ft.	In.
Pleistocene and Recent deposits			
11.	Soil, grading into loess at base	1	6
10.	Loess	15	..
Lafayette formation			
9.	Clay, sandy and bedded, below; angular chert pebbles in clay above; a re-worked base	3	..
Midway formation			
8.	Sand and limonite beds; cross-bedded, clayey above, stringers of clay pebbles in base	10	..
7.	Sand, very fine, ash-colored; limonite concretions, clay lenses near top; "Petrified hickory"; wash shows greensand	30	..
	Sharp break		
Ripley formation			
6.	Clay, chocolate, stained by plant remains	..	6
5.	Sand, ash-colored and buff	8	..
4.	Covered	5	6
3.	Clay	3	..
2.	Limonite, concretionary	1	..
1.	Clay shale, micaceous, thinly bedded, numerous pyrite concretions; several seams colored dark by lignite and fragments of plants (approx.)	10	..
	Water level		

This horizon is replaced but a short distance below by clay and sand in which limonite and lignite streaks are common.

Section in ravine three quarters mile northwest of Chalk Bank

		Thickness Feet
Midway formation		
5.	Clay shale, dark	10
4.	Sand in loose beds, containing greensand; grades into clay above	4
3.	Conglomerate, rich in iron oxide; voids filled with sand	1
2.	Greensand, as above, a few quartz pebbles	3½
1.	Clay shale, impure	3

The greensand of the preceding section is about 30 feet higher than the base of the Chalk Bank section and is exposed in several hollows above Chalk Bank. Greensand is also reported from near low water mark at Hillerman's Landing, but was not seen in place.

Wilcox Group

The Wilcox group includes the youngest beds of Tertiary age in Illinois. They are exposed over the higher areas of southern Pulaski and Alexander counties. A section at Fayville of beds which are regarded as belonging to this horizon is as follows:

Section including the Wilcox group, at Fayville

		Thickness	
		Ft.	*In.*
7.	Soil	1	3
6.	Loess	10	..
5.	Clay and sand, ash-colored	4	..
4.	Sand, buff, partially cemented	5	6
3.	Conglomerate layer cemented by iron; pebbles up to 3 inches in diameter	1	6
2.	Clay, lignitic	3	..
1.	Clay, sandy, micaceous	4	..

On the land of the Aetna Powder Company other Wilcox deposits are found: 9 feet of light drab to gray laminated clay with partings of mica and an occasional thin seam of sand is exposed at the first separator house; and in the cut made for a railroad spur there are 20 feet of loose white sand. Pits dug for clay have penetrated similar sands in the Mountain Glen district of north central Union County, and the sand beds at Hillermans Landing and Grand Chain are also similar. These facts suggest but do not prove that the white clays above the sands at Mountain Glen and Grand Chain may be at the same horizon in the Wilcox group. The distribution and a similarity of elevation suggest that they are isolated deposits overlying an irregular erosion surface.

PLIOCENE SERIES

Certain beds formerly included in the Lafayette formation have recently been shown[1] to be parts of different deposits and to belong to several formations, most of which are as yet unnamed. "It is believed to be made up of unrelated or distinctly related materials that * * * consist in the main of more or less modified parts of the underlying formations, including some residuum and colluvium, and of terrace deposits of Pliocene and Quaternary age."[2]

The Pliocene deposits in Illinois show evidences of transportation and will probably prove to be terrace remnants. Chert pebbles, angular masses, and rounded quartz pebbles predominate. Lenses of clay or of clay and sand occur, generally below the gravel, and there is commonly sufficient fine material to fill all voids. The common color is red. The pebbles often show a polish akin to a desert polish over a maturely etched surface. Large masses display the same polish as do small rounded ones.

Huge masses of conglomerate are included within other conglomerates, perfect polished surfaces are a second time recoated with rough red iron cement, features which are to be taken as evidences of re-working, transportation, and redeposition.

[1] Shaw, E. W., The Pliocene history of northern and central Mississippi: U. S. Geol. Survey Prof. Paper 108 H, 1918.

[2] Op. cit., p. 161.

These beds may once have covered the older formations and overlapped them at the north. However that may be, erosion has since removed all but small terrace shoulders on the slopes or isolated remnants over the higher areas.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Loess Formation

Above the gravel and red clay horizon is a sheet of loess, which extends as a mantle over and beyond the embayment deposits and except where removed by erosion is everywhere present. It is composed of a porous, buff, silty clay which stands in vertical walls. In color it varies from yellowish brown to red. The thickness of this bed varies from place to place, ranging from a mere trace to as much as forty or fifty feet.

RECENT SERIES

Alluvial Deposits

The latest deposits of this region, the river flood-plains, form the principal surficial covering over the continuous elongate lowland area which extends from Ohio River above Bay City westward past Brownfield, New Columbia, Belknap, and Ullin on the south, and Temple Hill, Grinnell, and Pulaski on the north. They extend from Mound City west to near Fayville where Cache River occupies a part of this flat which was at one time the flood-plain of Ohio River. Another smaller area extends from below Hamletsburg to near Brookport.

"There are two distinct flood-plains though not always present at one locality. The upper or 'second bottoms' lies 45 feet or more above low water, and has a much greater extent than the lower plain, more recently developed at a level about 20 feet above low water. The lower flat is subject to partial or complete overflow at the present time, while the upper is for the most part, at least, above high water.

"The composition of these alluvial deposits is commonly revealed along river bluffs and in water wells. Sandy clay predominates, but this gives way, on the one hand, to fine gray or blue clay or nearly normal loess, while, on the other, to beds of gravel one foot or more thick and composed of flint and sandstone pebbles commonly as much as two inches in diameter. Vegetal remains, leaves, and wood are often interbedded with the silts while other clays are darkly colored with organic matter.

"The thickness of the alluvium can be obtained only from well borings, and as these rarely penetrate more than a few feet to water, it is not possible to learn the thickness at many places in this area. At lower places along the Mississippi it is thought to be as much as 100 and 200 feet thick."[1]

[1]Purdy, R. C., and DeWolf, F. W., Preliminary Investigations of Illinois Fire Clay: Ill. State Geol. Survey Bull. 4, pp. 145-146, 1907.

These deposits are not utilized at the present time. In the days when pottery was manufactured at Metropolis, slip clay was dug from the Ohio River silt near that place.

ELEVATION OF THE ILLINOIS EMBAYMENT CLAYS

A study of the relative elevation of the various clay deposits is of interest as bearing on the mode of origin and age of the different clays. It is necessary, however, to remember that noted changes of elevation have taken place in areas not far distant from southern Illinois in recent times, as for example in the Reelfoot Lake district of northwestern Tennessee, and that similar changes may have affected this area.

Approximate present elevations of clay beds above sea level

Clay "diggins," Raum, Pope County	420 to 440
White and lignitic clays at Grand Chain, Pulaski County	425
Mountain Glen clays, Union County	400 to 460
Clay 1½ miles west of Alto Pass, Union County	625±
Clay west of Devonian ridge at Kaolin, Union County	560±
Clay east of Devonian ridge at Kaolin, Union County	560±
Clay in southern Jackson County	600 to 650

The first three clays are similar in many ways and all are lignitic except possibly the Raum clay, in the description of which no mention was made of lignite. The last four clays are similar, in that they are sandy and generally have a greenish gray tone.

Similarity in elevation of the first three clays listed above, namely, those at Mountain Glen, Grand Chain, and Raum, suggests that they may have been of the same age, though the isolation of their positions makes accurate determination of the age impossible. Terrace clay 100 feet or more above the better clay of the Union County area points to at least one period of clay formation subsequent to that of the Mountain Glen clay.

The fact that pure, white, plastic clays of this type are present in small isolated areas would seem to indicate that much greater quantities of such fine silt were washed into the larger embayment area from the extensive Mississippian limestone outcrops and that the present deposits are mere remnants. In most cases sandy impurities become mixed with the silt in transportation and the outer deposits are more sandy in texture. Such clays are found in the Wilcox group (La Grange formation). "The clays * * * vary from pure, fine-grained, plastic material to sandy, silty clays that are often dark from organic matter or black from lignite. The clays of the lower part of the formation are characteristically fine-grained, pure, plastic, and either very light colored or white."[1]

[1]Glenn, L. C., Underground waters of Tennessee and Kentucky west of Tennessee River, and in adjacent area in Illinois: U. S. Geol. Survey Water Supply and Irrigation Paper 164, p. 34, 1906.

As mentioned, clay dug near Hickory, Kentucky, and north of Mayfield is identical in color, texture, and other physical properties with that at Mountain Glen. That clay is of Wilcox age. All these evidences point to the Wilcox age of the Illinois clays.

The higher sandy terrace clays resemble the greenish gray clays at Wyckliff, Kentucky, and a later Wilcox age is suggested by their position.

The sandy, bedded clays of Massac and Pulaski counties are in older beds referred to the Midway and McNairy members.

Field and Laboratory Notes on the Embayment Clays

Field Notes by C. R. Schroyer
Tests by C. W. Parmelee

UNION COUNTY, MOUNTAIN GLEN AREA

PITS OF THE ILLINOIS KAOLIN COMPANY

The large pit, known as the "K" pit, of the Illinois Kaolin Company is located in the SW. ¼ sec. 35, T. 11 S., R. 2 W., about a quarter mile west of Kaolin Station on the Mobile and Ohio Railroad. This pit is approximately 200 by 300 feet and is about 80 feet deep at the west end where the lowest working encountered a light to orange colored sand.

There is a variation in the section from place to place about the walls. One section measured at the west end is as follows:[1]

Section measured at the west end of "K" pit of Illinois Kaolin Company

		Thickness *Feet*
6.	Loess at top	..
5.	Gravel	1
4.	Sand, white, micaceous; in places stained pink	10
3.	Sand, pink to dark purplish red, micaceous	10
2.	Clay, pink to red, highly plastic	15
1.	Clay, bluish white, highly plastic	15

In some places the entire section is sand, gravel, and loess, while at others clay extends from the gravel to the bottom of the pit. A sketch of the north wall made when the pit was visited in March, 1918, is given in Figure 47. The sand rises as a huge dome and cuts out the clay at its crest over a 40-foot width. Orange sand above is replaced by white with occasional buff below. Discoloration follows the line of contact between the sand and clay. White, purple, buff, and red are mottled in bands due to concentration of underground water circulation along channels of easiest movement. The iron content of the sand and the resultant firmness of cementation increase toward the contact with the clay. Yellow limonite is

[1]St. Clair, Stuart, Clay deposits near Mountain Glen, Union County, Illinois: Ill. State Geol. Survey Bull. 36, p. 13, 1917.

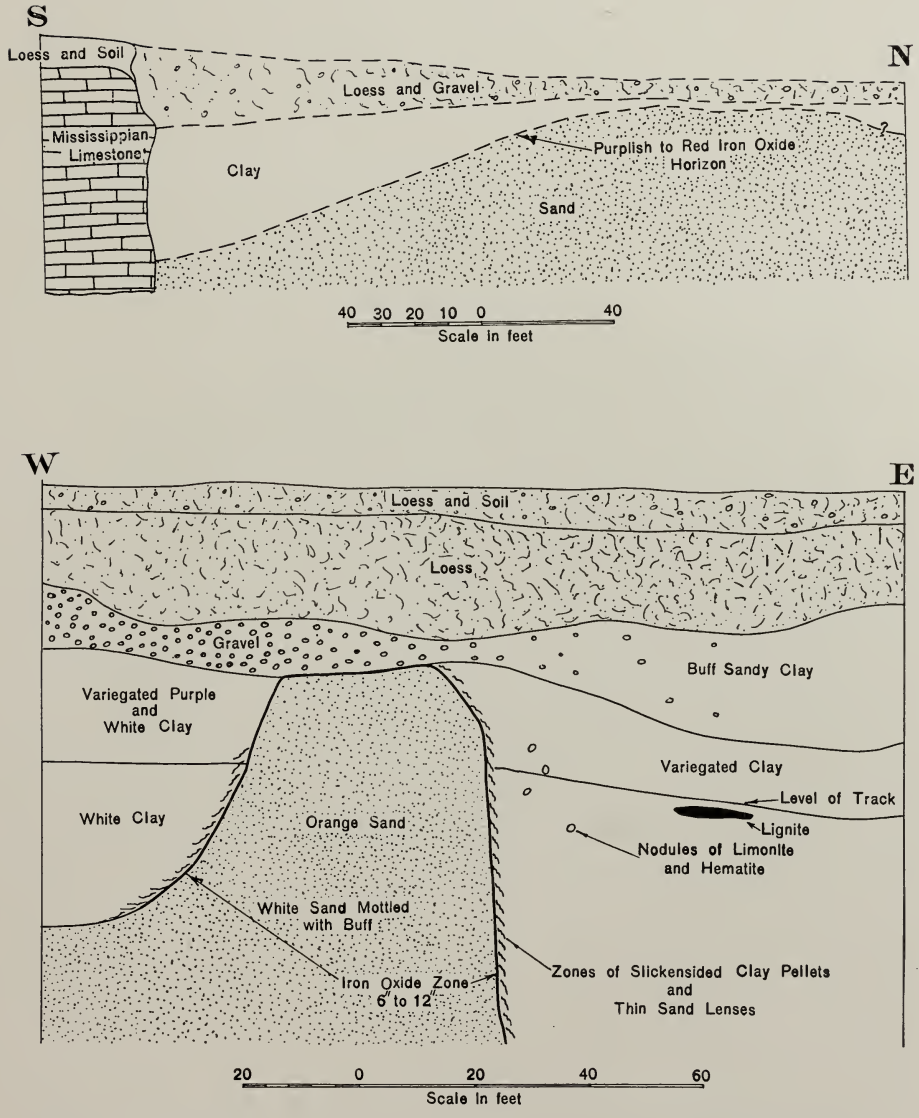


FIG. 47. Diagrammatic sketches of the "K" pit of the Illinois Kaolin Company. Above: North-south profile section. Below: Sketch of the north face.

evident, but Indian red hematite predominates. At each contact zone there is a layer of iron oxides, generally impure from admixtures of sand and clay, though several large hand specimens of pure hematite were broken from these seams. Beyond the contact this iron band grades from hematite through limonite into red, purple, and mottled clay. Concretions of iron oxide may be found 20 feet or more from the contact.

Along this zone of iron, more commonly on the side of the clay, are numerous lenses, pellets, and plate-like stringers of clay with perfect slickensided surfaces and coatings of felty flakes of white mica. Such smoothed zones may be seen out six feet or more from the contact, separated not

FIG. 48. View of the southwest wall of the "K" pit of the Illinois Kaolin Company.

uncommonly by thin sheetings of sand. Lines of weakness extend far beyond these smoothed pellets, as shown in some places by checks in the clay, and in others only upon the weathering of the clay after exposure. Such lines are roughly parallel to the line of contact between the sand and clay. A few larger spalls of clay are caught and completely surrounded by the sand. Rarely is a large quantity of sand included within the clay, but if so included, it is drawn out into a thin flattened stringer bounded on each side by slickensided clay pellets.

These zones have so conspicuous a color when freshly exposed that they stand out and can be traced by the eye from the far side of the pit. The purple iron zone is reported to have been lower in the direction of the

limestone wall at the south and to have everywhere been underlain by sand. This relation of sand to clay, due to a doming of the sand up into and through the clay may explain many of the irregularities found in the clay of the district. Later drilling is reported to have revealed another body of clay with almost vertical walls northwest of the present pit, presumably adjoining the sand dome on the northwest.

Pyrite occurs at certain levels near one edge and a few thin lenses of lignite were found.

Details of the working of this pit and the surrounding property are given by St. Clair in State Geological Survey Bulletin 36 and will be repeated here only briefly. The clay is dug by steam shovel, hauled by small steam engine to a large shed east of the mouth of the pit, cleaned by hand, graded, and stored or loaded directly onto the Mobile and Ohio Railroad switch. Large quantities of clay have been dug and one wall now shows an exposure of 20 feet of variegated, purple and white clay above 35 feet of white and bluish white, highly plastic clay. The greatest overburden is 40 feet with an average of 15 feet or perhaps more.

The southwest wall of the "K" pit is cliff of limestone (fig. 48), and the relation of the clay to this wall suggests that it was deposited in depressions bordered at least partly by the limestone.

Two other pits designated as the "G" and the "F," are located on this same property, north and west of the present "K" pit.

PITS OF THE FRENCH CLAY BLENDING COMPANY

The pit of the French Clay Blending Company in the NW. ¼ sec. 35, T. 11 S., R. 2 W., was not in operation when visited. Judging from former records and from the fact that clay outcrops in a gully not far from the pits, the workings probably represent one of the largest remaining clay deposits of the area. One exposure of bed rock just southeast of the former pit is an unfossiliferous limestone with chert, which dips 14° NE. and strikes N. 28° W.

This clay was mined by shafts and connecting drifts, and by open pits. No sample was obtained.

GOODMAN PIT

Location and Method of Working

The pit owned and operated by Dr. Goodman of Cobden is located in the NW. ¼ sec. 2, T. 12 S., R. 2W. (fig. 49). The clay is obtained from shafts 14 by 14 feet, that are tightly cribbed, sheeted, and intercrossed with strong log braces set in about three feet from each side. When one shaft reaches the bottom of the clay it is abandoned and partly filled with the overburden from the next shaft which is dug so that it adjoins the old one

by half the length of one of its sides. This method recovers all the clay with a minimum working of overburden.

Stripping and digging from an open pit would reduce the cost of production. Prospecting by drill and pits would outline the shape of the deposit and the quantity available, and thus indicate the development justified.

Geology

The log of the working shaft, which was down about 100 feet when visited March, 1918, is as follows:

Fig. 49. View of Dr. Goodman's mine in the NW. ¼ sec. 2, T. 12 S., R. 2 W.

Log of the Goodman shaft in the NW. ¼ sec. 2, T. 12 S., R. 2 W.

Description of strata	Thickness *Feet*	Depth *Feet*
Loess	10	10
Gravel	1	11
Sand	2	13
Clay		
Pink clay (Sample No. 27)	27	40
White and pink (Sample No. 28)	30	70
White clay (to bottom of pit) (Sample No. 25)	30+	100
Sand, orange	..	..

The pink clay is reported to have an approximately uniform thickness over the deposit so far as worked. The white clay is increasing in quantity and quality as the pits are driven farther south in the ridge, for accompanying the rise in the upper surface is a lowering of the base. The results of tests made on samples No. 27, No. 28, and No. 25 are given on pages 53-56.

One small pocket of lignite has been found in the white clay and five or six perfectly smoothed and polished pebbles have been taken from the lower levels. The top of the clay rises south under the ridge and the relation to

Fig. 50. Sketch made at the mouth of the Goodman shaft.

the sand at the base suggests irregularities similar to those in the Illinois Kaolin Company's pit. A sketch made at the mouth of the shaft (fig. 50) shows the relation of this thickening to the overlying sand and gravel. In addition to the samples noted above, a sample of the "Chocolate" (sample No. 30) clay which is found associated with the white clay was taken, and the results of tests made on it are given on pages 56 and 57.

MINES OF FREDERICK E. BAUSCH

LOCATION AND METHOD OF WORKING

The present Bausch workings include three pits. No. 1 mine, located near the center of sec. 35, T. 11 S., R. 2 W., is reported to have reached a depth of 55 to 60 feet. Tunnels driven from shafts at various levels total 500 feet. The overburden of ten feet has two feet of gravel at the base. The clay is underlain by white sand. Both pyrite and lignite are present commonly occurring together. Pink clay is wanting in this deposit.

At mine No. 2 in the NE. cor. of SW. ¼ sec. 35, T. 11 S., R. 2 W., the section is given as follows:

Section measured at Bausch Mine No. 2 in sec. 35, T. 11 S., R. 2 W.

		Thickness *Feet*
3.	Soil	15
2.	Sand, reddish, coarse, gravelly (vertical seam)	40
1.	Clay, one side of shaft pink, other side, white	25

Mine No. 3 is located in the SE. ¼ sec. 27, T. 11 S., R. 2 W., near the center of the east line of the section, about one mile from the loading stage at Kaolin. The mining is by shaft and tunnels, and the clay is said to be drifting down following the quicksand below. At the present working it is 30 feet thick, with an overburden of about 18½ feet. The clay is assorted and trimmed by hand.

Three grades of clay are made: namely, A1 or No. 3 (sample No. 121), Blue No. 2 (sample No. 122), and No. 1 (sample No. 9); tests were made on these samples with the results given on pages 57 to 59.

GEOLOGY

This pit is located between upthrown Mississippian limestone at the east and the Devonian highlands at the west. The limestone outcrops in a scarp less than 200 yards east of the pit, dips 20° E., and strikes N. 15° W. Drillings by the Illinois Kaolin Company south of this pit near the NE. cor. sec. 34 show only black pyritic Devonian shale. The clay is evidently in an isolated depression.

ELMER GANT MINE

The Gant clay mine is located in the SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W., about 1½ miles by wagon road from the Mobile and Ohio Railroad switch at Kaolin. The clay is mined from a shaft 14 by 14 feet with "lead tunnels." It is drawn out by horse and bucket and the better grades are assorted and trimmed by hand. Three grades are made, pink and white mottled, No. 3 (sample No. 29); white, No. 2 (sample No. 23); and the bluish white, No. 1 (sample No. 26); tests of these samples are reported on pages 59 to 61.

The overburden of loess and gravel is from 6 to 12 feet thick. Several test pits have been dug and borings have been made; one is reported to have gone 73 feet in clay. The present workings are 35 feet deep.

But very small amounts of lignite have been found associated with the clay and no pyrite is reported.

This clay is obtained from a hollow on the west side of a loess-covered ridge. On the opposite side, beds of crystalline Mississippian limestone are found in place and loose slabs extend up to a level which is not far below the top of the clay.

T. P. SIFFORD PIT

A pit opened by T. P. Sifford is located on the Mary A. Walker farm in the SW. ¼ sec. 1, T. 12 S., R. 2W. The overburden does not exceed 15 feet. The present shaft, a double hoist, 15 by 10 feet, has been dug 62 feet deep into 50 feet of clay. A boring, it is said, penetrated 72 feet of clay. White clay is reported to be above and pink below. In one side of the pit a streak of lignite was associated with concretions of pyrite and marcasite.

This pit is little more than a quarter of a mile east of the Gant pit and is separated from it by a high loess-covered ridge and the crystalline limestone mentioned above. A pit 35 feet deep, dug 100 feet south of the shaft, penetrated nothing but orange sand, below the gravel, indicating a condition similar to that found in the Illinois Kaolin Company's pit.

No clay has been shipped from this pit.

MADDOX AND NIXON PIT

The Maddox and Nixon clay mine is located in the NE. ¼ sec. 10, T. 12 S., R 2 W., less than half a mile west of the loading switch on the Mobile and Ohio Railroad. Six 14- by 14-foot cribs have been mined from clay reported to be from 12 to 35 feet thick. The top of the clay rises and the base lowers as the pits are driven farther back into the ridge. Three grades of clay have been obtained: No. 1, blue clay (sample No. 11); No. 2, white clay (sample No. 16); and No. 3, pink and white mottled clay. The best grade comes from the lower parts of the pits. Results of tests made on samples No. 11 and No. 16 are given on pages 61 and 62.

The overburden is about 12 feet thick. White sand underlies the clay.

SMALLER PITS

Much prospecting done outside of the main clay area, has discovered a few small lenses of clay.

Wm. Ferril dug a small amount of sandy clay from pits in the NE. ¼ sec. 3, T. 12 S., R. 2 W. Much sand and gravel accompanies this clay and the quantity is probably small.

Samples No. 18 and No. 22 were taken from this property, and reports on their testing are given on pages 62 and 63. The latter is Ferrill's best or "Blue" clay.

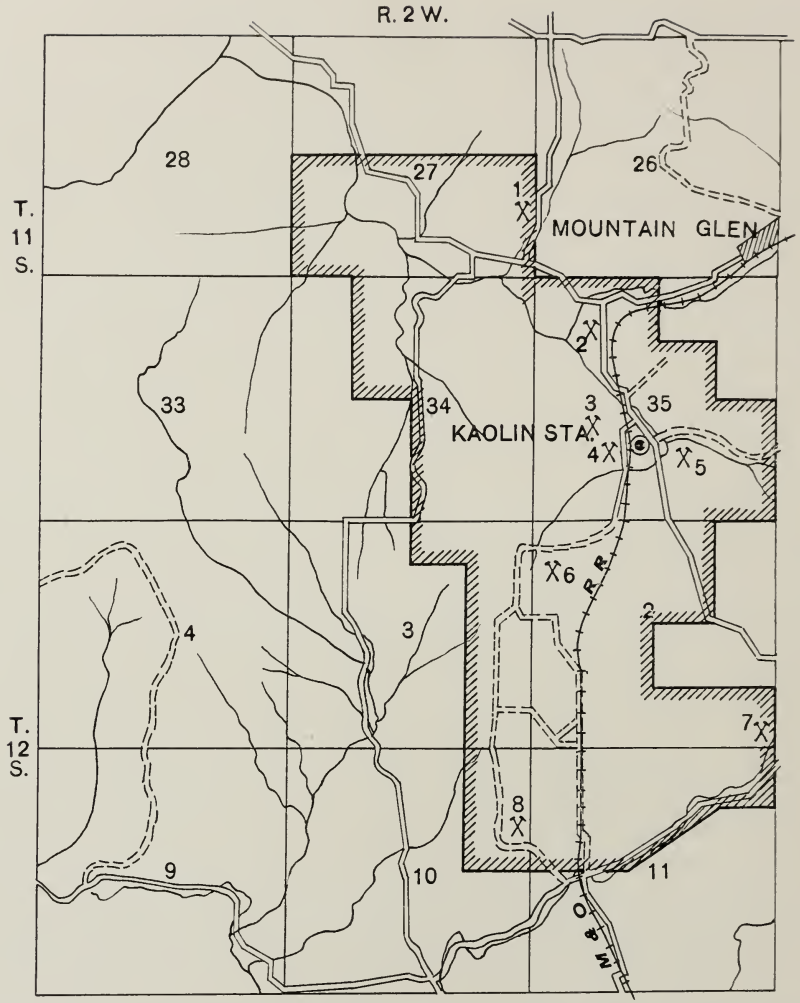


FIG. 51. Map of the Mountain Glen area. The lands known to include deposits of clay having proven or probable commercial value are indicated by shading.

The following list contains the names of the owners of the several pits or mines shown on the above map:

1. Frederick E. Bausch (Mine No. 3)
2. French Clay Blending Company
3. Frederick E. Bausch (Mine No. 2)
4. Illinois Kaolin Company (3 pits)
5. Frederick E. Bausch (Mine No. 1)
6. Dr. Goodman
7. Elmer Gant
8. Maddox and Nixon

Another pit has been opened in the NE. ¼ sec. 17, T. 11 S., R. 2 W., where the clay is sandy and mixed with red surface clay at the top. No clay has been shipped. This is at an elevation of about 625 feet above sea level.

Much other prospecting has been done, and it is hardly likely that there are many deposits of the high grade clay that are not now known. Figure 51 is a map of the Mountain Glen area on which the lands known to include deposits of clay having proven or probable commercial value, are indicated by shading.

COMPARISON WITH THE CLAYS NEAR MAYFIELD, KENTUCKY

Pink and white clay reported to be 30 feet thick is dug on the D. M. Chapman farm 2½ miles west of Hickory, Kentucky. The pink clay is mostly at the top and there is some coloring from lignite. Similar clay is also dug 3 miles west of Hickory, where the average thickness is about 16 feet. These clays are in the lower part of the Wilcox group.

In color, texture, and physical properties these clays resemble the Union County clays of Illinois. The presence of lignite and the lack of stratification is common to both.

COMPARISON WITH THE CLAYS OF LUTESVILLE, MISSOURI

In texture and color the clays of Union County, Illinois, are similar to the kaolin of the Lutesville district, Missouri. Those clays, however, are thought to occupy the same position as the bed rock from which they were derived and are a residual product from the decay of a sedimentary rock, presumably a cherty limestone interbedded with thinner beds of siliceous strata. This decay seems to have been localized along fault planes. In the Bausch mine, two miles west of Glen Allen, a sandstone bed is now represented by three feet of quartzite 30 feet below the top of the shaft. This is interbedded with white kaolin above and below. Traces of former bedding planes are evident in the walls of the mine and irregular seams of chert parallel the bedding and sets of fracture lines. Large numbers of chalcedonic nodules suggest considerable solution, concentration, and redeposition of silica, though part of the siliceous material is still distributed as stringers and beds of granular white "tripoli." In some of the concretionary masses such silica has served as the nucleus of deposition and is now enclosed in a coating of hard, banded chalcedony.

The clay varies from white through grayish-white to reddish pink.

The presence of lignite and an occasional pebble in the Illinois clays is proof of reworking, transportation, and redeposition, or, in other words, of a sedimentary clay in contrast to the similar clay in Missouri which is still residual.

RESULTS OF TESTS

UNION COUNTY, MOUNTAIN GLEN AREA

Samples F, G, and K[3]

(Illinois Kaolin Company; SW. ¼ sec. 35, T. 11 S., R. 2 W.)

Three samples of clays received from the Illinois Kaolin Company prior to the visit of members of the Survey were tested with the results as shown under the headings F, G, and K[3].

		(F)	(G)	(K[3])
Water of plasticity	*per cent*	37.4	...	41.4
Shrinkage water	*per cent*	18.9	...	24.0
Pore water	*per cent*	18.5	...	17.4
Modulus of rupture	*lbs. per sq. in.*	142.5	145	195.6
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	259.5	163.7	202.8
Slaking test	*min.*	21	21½	.....

Screen test:—

(Sample F)

Mesh	Residue *Per cent*	Character of residue
20	.13	Silica and particles of coal
40	.10	Quartz particles, some colored with iron
60	.47	Quartz particles, rounded, colored with iron
80	.13	Clear quartz particles
120	3.14	White and brown quartz particles
200	1.4	White quartz particles

(Sample G)

120	.37	White quartz particles
200	.22	Quartz sand

Drying shrinkage:—

	Per cent (F)	(G)	(K[3])
Linear; wet length	5.26	5.27	10.0
Linear; dry length	5.68	5.68	11
Volume	28	29	40.2

Burning test:—

(Sample F)

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	19.9	.....	9.2	.....
5	6.6	Cream	11.0	
9	3.2	Gray exterior; bluestoned.....	11.5	
12	3.96	Tan exterior; bluestoned.....	10.8	Hackly fracture
13½	3.68	.....	10.6	
15	4.2	Tan exterior; bluestoned.....	11.0	

(Sample G)

2	25.1	White	5.9	.....
5	18	Cream white	8.4	Hackly fracture
9	7.55	Cream	9.2	
12	2.81	.....	9.4	
13	2.57	.....	11.4	
15	3.26	Tan exterior; bluestoned	11.1	Hackly fracture; veining of fine cracks in the surface

(Sample K³)

04	34	Cream white	4.3	Hackly fracture
02	33	Cream white	4.8	
2	20	Cream white	...	
5	21	Cream white	9.0	
9	7	Cream white	12.0	
13	3	Gray white; bluestoned	...	Fine-meshed surface cracks
14	3	Tan exterior; bluestoned	13.0	

	(F)	(G)	(K³)
Fusion test	....	Cone 29/30	Cone 32

Summary

Samples F, G, and K³ are all similar in appearance, excepting for the slight differences in color. In plasticity and working properties there is little difference. They are all similar in having a higher strength when mixed with standard sand than when tested as pure clay. The bonding strengths of K³ and F are medium. G is low. The amount of residue left on the various sizes of screen mesh is exceedingly small. The drying shrinkage of K³ is medium high while that of F and G is medium low. The burning shrinkages at cone 9 are high for all three samples. The sample F is well vitrified at cone 9, while the other samples are slightly less so at the same temperature. These are refractory clays, which do not overburn at cone 15.

These clays belong to a class which has been found very useful for admixture with others in the production of close burning refractory bodies; also of bodies not of refractory nature but of close texture or having a high content of non-plastic material which must be well bonded together.

Sample No. 27

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft pinkish-colored clay, varying somewhat in shade and showing an occasional yellowish streak. The working properties of the plastic mass are good. It flows through a die satisfactorily when in a stiff condition.

Water of plasticity	*per cent*	36.4
Shrinkage water	*per cent*	8.2
Pore water	*per cent*	28.2
Modulus of rupture	*lbs. per sq. in.*	265
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	120.9
Slaking test, average	*min.*	20

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.015	Fine sand
150	.57	Sand
200	.63	Sand

Drying shrinkage:—

	Per cent
Linear; wet length	6.7
Linear; dry length	7.38
Volume	29.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	23	Pink	9.57	.....
5	14	Pink	10.85	Hackly fracture
9	2.6	Light tan; bluestoned	12.0	Hackly fracture
12	1.6	Light tan exterior; heavily bluestoned	.....	.....
13½	7	Light tan exterior; heavily bluestoned	9.27	.....
15	6.24	Dark buff; bluestoned	10.4	Fine mesh of cracks

Fusion test:—It deforms at 29/30 cone.

Summary

The strength of the unburned clay is medium. The bonding strength is medium low. The percentage of residues left on the screens is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is complete at cone 12. The apparent overburning at cone 13½ may be due to the development of small cracks in the test piece during the firing since there is no further increase in the porosity at cone 15. It is a refractory clay. This clay is adapted for use in the manufacture of refractories, especially those which burn densely. This clay burns to a very dark color for a fire clay.

Sample No. 28

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft clay varying in color from cream to red. The plastic mass is readily molded. It flows poorly through the die.

Water of plasticity ..... *per cent* 38.3
Shrinkage water ..... *per cent* 18.7
Pore water ..... *per cent* 19.5
Modulus of rupture ..... *lbs. per sq. in.* 192.7
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 151.8
Slaking test, average ..... *min.* 10.5

Drying shrinkage:—

	Per cent
Linear; wet length	7.45
Linear; dry length	8
Volume	30.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	30	Pinkish white	7.42	
3	16	Light cream	11.1	
4	10.1	Light cream	11.7	
6	7	Cream	12.0	Hackly fracture
9	3.0	Cream; bluestoned	12.9	
12	2.5	Gray; bluestoned	13.5	Vitreous; hackly fracture
13	3.4	Cream; bluestoned	13.6	
15	4.7	Tan exterior; bluestoned	13.4	Hackly fracture. Fine veining of cracks throughout test piece

Soluble salts:—Pieces burned at the low cones show strongly characteristic yellowish surface coating after soaking in water.

Fusion test:—It deforms at cones 32/33.

Summary

This clay has a medium low strength in the unburned condition. Its bonding strength is low. The absence of residues on the screens indicates a very fine-grained material. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is nearly complete at cone 12. The clay is highly refractory and is especially adapted to the manufacture of such wares, especially those which should burn dense at a low temperature.

Sample No. 25

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a white clay which shows a few reddish stains on the faces of fractures. Its working properties in the plastic condition are good. When the clay is in a stiff consistency it flows satisfactorily through a die.

Water of plasticity ..... *per cent* 39.5
Shrinkage water ..... *per cent* 19.4
Pore water ..... *per cent* 20
Modulus of rupture ..... *lbs. per sq. in.* 131.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 141.4
Slaking test, average ..... *min.* 12

Drying shrinkage:—

	Per cent
Linear; wet length	8.3
Linear; dry length	9.1
Volume	32

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	23.7	Cream	8.45	
5	20	Cream	9.15	
9	3.6	Gray; bluestoned	10.9	
12	0.7	Gray; bluestoned	11.9	Hackly fracture
13½	0.9		12.5	
15	3.0	Gray exterior; bluestoned	11.8	

Fusion test:—It deforms at cone 32.

Summary

The strength of the unburned clay is medium low. Its bonding strength is medium low. Practically no residues are retained on the screens. The drying shrinkage is medium. The total burning shrinkage at cone 9 is high. Vitrification is complete at cone 12. Overburning seems to be indicated at cone 15. It is quite possible that this appearance is due to the peculiar cracking of the piece rather than a real vesicular structure. It is a refractory clay. It is suggested that it will find important uses in the manufacture of refractories, especially those requiring a dense structure.

Sample No. 30

(Goodman pit; NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft clay of a cream color, shading into reddish. Its working properties in the plastic condition are good. It flows satisfactorily through a die when it has a stiff consistency.

Water of plasticity ..... *per cent* 44.2
Shrinkage water ..... *per cent* 21.4
Pore water ..... *per cent* 22.8
Modulus of rupture ..... *lbs. per sq. in.* 345
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 229.4
Slaking test ..... *min.* 13

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	1.46	Cream-colored sand
150	0.39	Cream-colored sand
200	0.24	Very fine sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.5
Linear; dry length	8.25
Volume	34.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	25.7	Cream	12.3	
5	1.3	Gray	13.7	
9	3.7		13.0	Hackly vitreous fracture
12	3.2	Tan exterior; bluestoned interior	13.2	
13	0.1		12.4	
15	5 3	Buff; bluestoned	11.4	Hackly vitreous fracture. Surface covered with mesh due to cracks

Soluble salts:—Piece burned at cone 2 after soaking in water shows greenish-yellow surface coating. Possibly vanadium salts.

Fusion test:—It fused at cone 32.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of residues is slight. The drying shrinkage is medium. The total

shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and overburning is slight if any at cone 15.

Suggested uses: Refractories, particularly crucibles and glass pots, etc.; architectural terra cotta, sanitary ware, stoneware.

Sample No. 121

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft white clay. When tempered with water, it becomes very plastic and inclined to be sticky. It flows very poorly through the die.

Water of plasticity ..... *per cent* 37.1
Shrinkage water ..... *per cent* 20.9
Pore water ..... *per cent* 16.2
Modulus of rupture ..... *lbs. per sq. in.* 191
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 123.3
Slaking test, average ..... *min.* 22+

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	Trace	Sand
80	Trace	.....
120	.09	Fine white sand
200	.24	White sand and mica

Drying shrinkage:—

	Per cent
Linear; wet length	7.4
Linear; dry length	8.2
Volume	33.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	18.3	Cream white	8.3	Hackly fracture
5½	13.0	Cream white	8.8	
9	1.68	Gray; bluestoned	9.6	
12	1.40	Gray; bluestoned	10.3	Hackly vitreous fracture
13½	2.0	Gray; bluestoned	9.8	
15	2.5	Gray exterior; bluestoned	9.3	

Fusion test:—It deforms at cone 30.

Summary

The clay has a medium low strength and medium low bonding strength. The amount of screen residues is negligible. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9 and the clay is not overburned at cone 15. The clay is refractory.

This is the type of clay which is useful in the manufacture of dense burning refractories.

Sample No. 122

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft white clay which becomes very plastic when tempered with water. It is also somewhat sticky. It flows badly when forced through a die.

Water of plasticity ..... *per cent* 37.9
Shrinkage water ..... *per cent* 20.6
Pore water ..... *per cent* 17.3
Modulus of rupture ..... *lbs. per sq. in.* 177.0
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 136.5
Slaking test, average ..... *min.* 29+
Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.25	White sand
200	.10	White sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.4
Linear; dry length	7.8
Volume	35

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	20.0	Cream white	8.0	
3	13.3	Cream white	....	Cracked along lines of differential flow
6	**10.0**	**Darker cream white**	....	
9	**1.3**	**Gray; bluestoned**	....	
12	2.8	Gray	9.7	Hackly fracture
13½	2.4	Gray	10.4	
15	3.3	Gray to tan exterior; bluestoned	10.2	

Fusion test:—Down at cone 32. Not vesicular.

Summary

The strength of this clay with and without the addition of standard sand is medium low. It has a very fine texture, leaving hardly more than a trace of residue upon the screens. The drying shrinkage is medium and the total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9 and the slight increases in porosity at the higher cones is apparently due to the formation of fine cracks which permeate the mass, rather than due to overburning. It is a refractory clay.

Suggested Uses: This clay belongs to the type of refractory clays which is of importance in the preparation of refractory wares having a dense structure. It is also similar to the architectural terra cotta and stoneware clays, although it is doubtful that it could be used alone to advantage for the latter purpose.

Sample No. 9

(Frederick E. Bausch mines; near Mountain Glen)

This is a soft clay of a pink color with streaks of brownish yellow and red. Its working property is fair, and it is rather sticky. Its conduct when flowing through a die is fair.

Water of plasticity ..... *per cent* 32.7
Shrinkage water ..... *per cent* 23.5
Pore water ..... *per cent* 9.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 104.4
Slaking test, average ..... *min.* 19
Fusion test:—It deforms at cone 31.

Summary

This clay is slightly more refractory than Nos. 121 and 122 but similar to them in its properties in both the unburned and the burned condition.

Sample No. 29

(Elmer Gant mine; SE. ¼ SE ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft white clay, marked by a few yellow and a few black veins. Some of the pieces are of a pronounced yellowish color. Its working properties in the plastic condition are good except that it is somewhat sticky. Its conduct when flowing through a die is fair.

Water of plasticity ..... *per cent* 35.8
Shrinkage water ..... *per cent* 18.7
Pore water ..... *per cent* 17.1
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 286.12
Slaking test, average ..... *min.* 16
Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	0.45	White sand
200	0.23	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	6.2
Linear; wet length	5.75
Volume	30.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
1	20.4	Light cream	7.4	
2½	11.3	Light cream	9.6	
3	10.6	Light cream	9.6	
6	2.3	Cream	10.0	
8½	2.0	Cream; slightly bluestoned	....	Hackly fracture
9	2.1	Cream; slightly bluestoned	....	
12	1.9	Cream; bluestoned	11.0	
13	2.2	Cream; bluestoned	11.0	
15	3.0	Tan exterior; bluestoned	9.6	

Fusion test:—It deforms between cones 32 and 33.

Summary

This clay has medium strength. The percentage of residue is slight. The drying shrinkage is medium. The total shrinkage at cone 12 is medium high. Vitrification is nearly complete at cone 6. Suggested uses are refractories, especially for crucibles and other dense wares, architectural terra cotta, stoneware, sanitary ware.

Sample No. 23

(Elmer Gant mine; SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a white soft clay which has some veins of red through it. Its working properties in the plastic condition are good. It flows fairly well through a die.

Water of plasticity ..... *per cent* 35.8
Shrinkage water ..... *per cent* 19.2
Pore water ..... *per cent* 16 6

Modulus of rupture ..... *lbs. per sq. in.* 311.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 302.3
Slaking test, average ..... *min.* 23
Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	.....
40	Trace	.....
60	Trace	.....
120	0.2	White sand
200	0.43	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	7.7
Linear; wet length	7.1
Volume	32.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	12.1	Cream white	10.0	.....
3	4.8	Cream white	9.0	.....
6	2.6	Cream; bluestoned	9.5	Hackly vitreous fracture
9	2.4	Cream; bluestoned	10.0	Vitreous fracture
12	2.9	Bluestoned	10.0	Vitreous fracture
13	1.1	Light tan exterior; bluestoned.	.....	Vitreous fracture
15	2.0	Tan exterior; bluestoned	10.0	Fine closed cracks on the surface

Fusion test:—It deformed at cone 32.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of screen residues is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is complete at cone 13. It is a refractory clay. It is suggested that it will be found of use in the manufacture of refractories requiring a densely burned body at a low temperature, such as crucibles.

Sample No. 26

(Elmer Gant mine; SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft white clay which may be brought to a good plastic condition with the development of some stickiness. It flows through a die satisfactorily when it is in a stiff condition.

Water of plasticity ..... *per cent* 41.5
Shrinkage water ..... *per cent* 25
Pore water ..... *per cent* 16.5
Modulus of rupture ..... *lbs. per sq. in.* 259.0
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 137.5
Slaking test, average ..... *min.* 34
Drying shrinkage:—

	Per cent
Linear; dry length	8.4
Linear; wet length	7.64

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	16	.....	10.2	.....
5	1.4	Gray white	10.7	
9	1.8	Stoneware gray	11.3	
12	2.8	Light tan exterior; heavily bluestoned	11.0	Hackly, vitreous fracture
13	3.27	.....	10.0	
15	3.0	Gray exterior; bluestoned.....	9.1	Hackly fracture

Fusion test:—It deformed at cone 33.

Summary

The strength of the unburned clay in the dry condition is medium. The bonding strength is medium low. It leaves no residues on the screens. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 5. It is highly refractory clay. It is suggested that it will find use in the manufacture of refractories, especially those having a dense body.

Sample No. 11

(Maddox and Nixon mine; NE. ¼ sec. 10, T. 12 S., R. 2 W.)

This is a plastic clay of a white color. It has good working properties and flows through a die quite satisfactorily.

Water of plasticity .....*per cent* 32.9
Shrinkage water .....*per cent* 23.5
Pore water .....*per cent* 9.3
Modulus of rupture .....*lbs. per sq. in.* 43.4 (?)
Slaking test, average .....*min.* 6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	None	.....
60	0.03	White sand
80	0.03	White sand
120	0.8	White sand, some mica
200	2.1	White sand, some mica

Drying shrinkage, linear; dry length.....*per cent* 4.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*
02	39.6	Light cream	3.8	8.3
1	38.4	Light cream	4.5	9.0
3	31.1	Light cream	7.4	11.9
5	28.8	Dark cream	9.0	13.5
7	15.6	Dark cream	9.9	14.4
9	12.9	Light brown	11.2	15.7
13	6.9	Light brown	....	....

Fusion test:—It deforms at cone 33.

Summary

The percentage of screen residues is slight. The drying shrinkage is medium low. The total shrinkage at cone 9 is high. Vitrification is incomplete even at cone 13. It is a highly refractory clay. It is suggested that it will find use in the manufacture of refractories of a high grade.

Sample No. 16

(Maddox and Nixon mine; NE. ¼ sec. 10, T. 12 S., R. 2 W.)

This is a soft clay of nearly white color. Its working property is good. Its conduct when flowing through a die is satisfactory.

Water of plasticity ..... *per cent* 28.3
Shrinkage water ..... *per cent* 10.8
Pore water ..... *per cent* 17.5
Modulus of rupture ..... *lbs. per sq. in.* 64.1
Slaking test, average ..... *min.* 10.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	0.05	White mica and white sand
80	0.22	White mica and white sand
120	5.3	White sand
200	5.4	White sand

Drying shrinkage, linear; dry length ..... *per cent* 4.3
Volume ..... *per cent* 17.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	
02	35.7	Light cream	2.1	6.4	
1	35.2	Light cream	2.1	6.4	
3	32.2	Light cream	3.3	7.6	Conchoidal Fracture
5	20.4	Light cream	7.4	11.7	
7	19.6	Light cream	8.0	12.3	
9	17.8	Light cream	9.2	13.5	
13	13.0	Dark gray	9.7	14.0	

Fusion test:—It fused at cones 30/31.

Summary

The strength of this clay is low. The percentage of screen residues is considerable. Its drying shrinkage is low. The total shrinkage at cone 9 is medium high. It is not completely vitrified even at cone 13. This is a refractory clay and it will be found useful in the manufacture of refractories.

Sample No. 18

(Wm. Ferril pit; NE. ¼ sec. 3, T. 12 S., R. 2 W.)

This is a soft white clay with occasional yellow discolorations. Its working property is good. It flows satisfactorily through a die.

Water of plasticity ..... *per cent* 33.2
Shrinkage water ..... *per cent* 8.9

Pore water .....*per cent* 24.6
Modulus of rupture:—The test pieces prepared for the determination of its strength proved to be too weak to be tested.
Slaking test, average.....*min.* 6
Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	None	.....
40	Trace	.....
60	.04	Fine white sand
80	0.2	Fine white sand
120	0.7	Fine white sand
200	0.9	Fine white sand

Drying shrinkage, linear .....*per cent* 3.1
Volume .....*per cent* 12.5
Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
02	40.9	White	1.9	5.0	.....
3	38.6	White	5.6	8.7	.....
5	36.3	White	6.2	9.3	.....
9	29.1	White	9.0	12.1	.....
13	0.05	White	...	....	Contains very fine reddish specks

Fusion test:—It deforms at cone 33/34.

Summary

The strength of the clay is very low. The percentage of screen residues is slight. Its drying shrinkage is medium low. The total shrinkage at cone 9 is medium. Vitrification is incomplete even at cone 13. It is a highly refractory clay. It is suggested that this clay will prove to be of value when used with stronger clays in the manufacture of high grade refractories.

Sample No. 22

(Wm. Ferril pit; N.E. ¼ sec. 3, T. 12 S., R. 2 W.)

This is a moderately hard clay of a light gray color. It has good working properties in the plastic condition and flows satisfactorily through a die.

Since only a small sample was secured for the preliminary test and subsequent attempts to obtain more material were unsuccessful because the face of the pit was inaccessible, complete test could not be made.

The fairly long period required for slaking may indicate a clay of high bonding strength. The fusion test is very satisfactory.

Suggested uses: This clay will be of value in the manufacture of refractories and possibly of particular interest to manufacturers of crucibles.
Slaking test, average .....*min.* 42
Fusion test:—It fuses at cone 32.

MASSAC COUNTY

PADUCAH POTTERY COMPANY'S PIT

The Paducah Pottery Company has a clay pit on the east side of the Chicago, Burlington and Quincy Railroad half a mile north of Choat, in the NE. cor. sec. 17, T. 15 S., R. 4 E. The clay body is lens-shaped and the accompanying sketch (fig. 52) shows the relation to the sandstone and gravel above and the sandstone below. The grayish-white laminated clay is 14 feet 4 inches thick, and 2 feet 10 inches of reddish brown clay above are discarded with the overburden. The clay is loaded at Choat and shipped to the plant at Paducah.

No tests have been made to determine the extent of the clay.

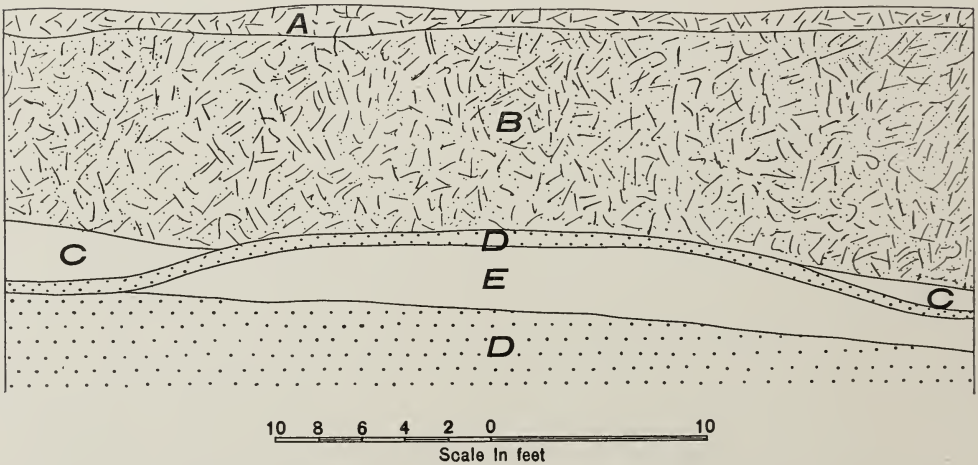


FIG. 52. Sketch showing the clay body and its relations to the surrounding strata at the Paducah Pottery Company's clay pit north of Choat.

A Soil.
B Loess.
C Chert pebbles, red clay, and quartz gravels.
D Sandstone, cemented by iron.
E White clay, laminated with thin sheets of fine micaceous sand.

Shipments vary somewhat as the clay is needed at the pottery, but averaged in the spring of 1918 from one to two cars per week.

CLAYS FROM THE VICINITY OF ROUND KNOB

No clay is dug near Round Knob at the present time, though formerly clay was shipped to potteries at Metropolis and Paducah, and there is an abandoned pit a quarter mile south of Round Knob, in the SW. ¼ sec. 1, T. 15 S., R. 4 E. When operated this pit furnished three grades of clay,

white, blue, and gray, and had a working face of 8 to 10 feet.[1] Another pit nearby had 7 feet of clay. The overburden varied in thickness up to a maximum of 18 feet. Clay could still be obtained by removing a heavy overburden.

A sample was taken from the road gutter a half mile west of Round Knob, in the N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E., where the section is as follows:

Section half a mile west of Round Knob

		Thickness *Feet*
4.	Gravel, rises with the hill	2 to 6
3.	Clay, red	4
2.	Clay, white and pink, sandy, laminated; stains of iron oxide (sample No. 46)	6½
1.	Sand, red and white	1½

A report of the tests made on sample No. 46 is given on pages 65 and 66.

CLAY FROM THE OBERMARK PROPERTY

A well is reported to have penetrated 30 feet of clay on the C. G. F. Obermark farm in sec. 36, T. 14 S., R. 5 E. A thin sandy horizon lies about 4 feet below the surface and streaks of iron at other horizons. The clay is blue-gray, sandy, and of fair plasticity. The sample (Sample No. 47) was taken by boring in a creek bed. Ten acres or more of this clay is available under an overburden of not more than 6 feet. Similar clay has also been dug in sec. 6, T. 15 S., R. 5 E.

A sample (Sample No. 48) was taken from clay exposed along the road between secs. 8 and 9, T. 15 S., R. 6 E. This is an ash-colored, sandy, laminated clay, interbedded with seams of limonite and probably not of commercial value. These two samples (No. 47 and No. 48) were tested with the results given on pages 66 and 67.

RESULTS OF TESTS

MASSAC COUNTY

Sample No. 46

(N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E.)

This is a soft, very sandy clay, containing much mica. It is a cream color, mottled with brown and pink. When mixed with sufficient water, it develops a fair degree of plasticity and will flow through a die satisfactorily.

Water of plasticity	*per cent*	22.2
Shrinkage water	*per cent*	11.6
Pore water	*per cent*	10.6
Modulus of rupture	*lbs. per sq. in.*	217.4
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	214.0
Slaking test, average	*min.*	27

[1]Purdy, R. C., and DeWolf, F. W., Preliminary Investigations of Illinois Fire Clay: Ill. State Geol. Survey Bull. 4, p. 149, 1907. See description of sample D28.

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	Trace	Pyrites, sandstone and mica
40	Trace	Pyrites, sandstone and mica
60	2.9	Mica and sand
80	1.7	White sand
120	36.2	White sand
150	13.5	White sand
200	5.9	White sand

Drying shrinkage, linear ..... *per cent* 2.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	36.7	Light brownish red	+0.5	
06	35.4	Light brownish red	+0.6	
04	35	Light brownish red	+0.8	
02	36.8	Light brownish red	+0.6	The clay expands during burning
1	34.9	Light brownish red	+0.8	
3	36.5	Light brownish red	+0.6	The burned pieces are very weak
5	36.3	Darker brownish red	+0.5	
7	35.3	Darker with iron specks	+1.0	
9	36.0	Darker with iron specks	+0.7	
11	35.5	Darker with iron specks	+0.9	

Fusion test:—It deformed at cone 31.

Summary

This is a clay of medium strength, much higher than might be expected considering its very sandy character. The bonding strength is medium. The percentages of screen residues are high. The drying shrinkage is low. Because of its sandy nature, the clay has a high and nearly constant porosity at all temperatures showing no sign of vitrification. This also explains the reason for the fact that it does not shrink but expands slightly at all temperatures.

Suggested uses: The lack of strength of the unburned clay will restrict its usefulness to admixtures with other clays. Such sandy clays often have a distinct usefulness. Because of its high fusion test it should be of use in refractories.

Sample No. 47

(C. G. F. Obermark farm; sec. 36, T. 14 S., R. 5 E.)

This is a dark colored, moderately hard clay. It has a medium plasticity when mixed with 28.5% water and in that condition shows rather poor flowing properties when squeezed through a die.

Water of plasticity ..... *per cent* 25.3
Shrinkage water ..... *per cent* 16.0
Pore water ..... *per cent* 9.3
Modulus of rupture ..... *lbs. per sq. in.* 365.8
Slaking test, average ..... *min.* 10
Drying shrinkage, linear ..... *per cent* 6.8

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Total shrinkage	Remarks
	Per cent		*Per cent*	*Per cent*	
02	20.6	Dark cream	3.2	10.0	.....
1	20.9	Dark cream	3.2	10.0	.....
3	19.6	Cream	3.2	10.0	.....
7	13.9	Gray	3.4	10.2	Conchoidal fracture
9	7.6	Gray	4.4	11.2	.....
10	9.5	Gray	...	....	No evidence of overburning

Fusion test:—Completely deformed and vesicular at cone 27.

Summary

This clay has a medium strength and medium drying shrinkage. The burning shrinkage at cone 9 is low. It is an open burning clay, which is incompletely vitrified at cone 10. The clay is not refractory.

Suggested uses: Face brick, stoneware, architectural terra cotta, sanitary ware.

Sample No. 48

(Secs. 8 and 9, T. 15 S., R. 6 E.)

This is a gray colored clay, mottled with brown. It contains much mica.

Slaking test, average .....*min.* 12.5

Fusion test:—No deformation at cone 27.

Summary

Insufficient material was received for complete test. However, it was found to be a refractory clay. The mode of occurrence with seams of limonite will prevent its use unless some method of purification is employed.

PULASKI COUNTY

CLAYS FROM THE VICINITY OF GRAND CHAIN

Clay was formerly dug for pottery near Grand Chain Landing and recently prospect pits have been opened at several places.

On the O. C. Field property pits have been dug in lenses of clay in the N.E ¼ sec. 9, T. 15 S., R. 2 E., where sample No. 38, tests of which are reported on pages 68 and 69, was taken. Both the bottom and the top are irregular, the top rising backward into the hill. A thickness of 20 feet of "black fat" clay has been exposed and is said to be underlain by blue and pink clay. The overburden of 3 feet of iron-cemented sand and gravel capped by loess thickens back over the ridge to a maximum of 15 feet. Clay has also been worked just above water level in Ohio River.

J. W. Joynt of Tamms, Illinois, has done considerable prospecting both by boring and pits in east half of sec. 4 and west half of sec. 3, T. 15 S., R. 2 E.

The clay is irregular and lenticular, ranging up to 12 feet as a maximum thickness. It is underlain by sand and overlain by gravel and loess. At pits in the N. ½ SE. ¼ sec. 4 the overburden will average 14 to 15 feet. This clay is white and resembles the clay from Mountain Glen. Clay from

the J. B. Hays farm in the SW. ¼ sec. 3 was of a chocolate color and contained lignite. The sample No. 37 was taken from a bin which contained clay from several test pits. Results of tests made are reported on pages 69 and 70.

A sample of white to gray plastic clay was taken from the road ditch two miles east of Grand Chain, where clay was in the gutter. The sample was obtained by boring. The section is as follows:

Section 2 miles east of Grand Chain

		Thickness	
		Ft.	*In.*
4.	Loess	16 to 32	...
3.	Gravel and red clay	4	6
2.	Clay, red	1±	...
1.	Clay, white to gray, plastic; exposed in road gutter	21	4

Sample No. 45 resampled as No. 1678 represents the upper portion. Sample No. 44 resampled as No. 1691 is from the lower portion of the deposit. Results of tests made on these two samples are presented on pages 70 to 72.

The top surface of the clay probably rises in the hill and if so the overburden would be less than given in the section. Other slopes show sand and impure clay at this horizon, proving that the clay is lenticular just as it is at other localities.

CLAY FROM CALEDONIA

A sample, No. 17, was taken from the dark gray clay exposed along the river bank at Caledonia (nearest railroad station, Olmsted). This comes from a 25-foot exposure and is a weathered product of the "soapstone" of Midway age.

The lower 14 feet of a section exposed in the river bluffs on the Barber farm, 2½ miles above Caledonia, in sec. 13, T. 15 S., R. 1 E., is of a gray, micaceous, thinly bedded clay. This contains some lignite and pyrite concretions and is said to extend down to low water level 20 feet below the bottom of the measured section. The overburden would be very thick, but hydraulic stripping would be possible at this place. Sample No. 37a (see page 73 for results of tests) is from this horizon. A very plastic white clay is exposed about 200 yards down stream at or near the water level. The exposure is small and the quantity uncertain.

RESULTS OF TESTS

PULASKI COUNTY

Sample No. 38

(O. C. Field pit; NE. ¼ sec. 9, T. 15 S., R. 2 E.)

This is a soft shaly material of a brownish color. It has good plasticity and flows smoothly through the die when a suitable amount of water is added.

Water of plasticity ..... *per cent* 38.6
Shrinkage water ..... *per cent* 24.6
Pore water ..... *per cent* 14.0
Modulus of rupture ..... *lbs. per sq. in.* 164.8
Slaking test ..... *min.* 50

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	0.27	Rock particles
40	0.25	Rock particles and sand
80	0.16	Rock particles and sand
120	1.69	Rock particles and sand
200	1.52	Rock particles and sand

Drying shrinkage:—

	Per cent
Linear; wet length	7.25
Linear; dry length	7.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	33.4	White	1.8	.....
02	24.7	Cream	3.4	Hackly fracture
2	18.1	Cream	6.0	.....
5	16.5	Cream	5.6	Hackly fracture
9	14.0	Cream	6.0	Hackly fracture, vitreous
13	3.7	Stoneware gray	7.0	Smooth fracture
14	2.8	Dark buff exterior, bluestoned	6.2	Appears to be overburned

Fusion test:—It deforms at cone 30.

Summary

The dry clay has medium low strength. The amount of residues left on the screens is low. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is practically complete at cone 13. It is a refractory clay and therefore suitable for use in the manufacture of such wares. The light color of the burned clay and its other properties make it available for architectural terra cotta, stoneware, and sanitary ware.

Sample No. 37

(Secs. 3 and 4, T. 15 S., R. 2 E.)

This is a soft clay containing a few nodules of carbonaceous matter. It is of a light gray color. It flows through a die fairly satisfactorily.

Water of plasticity ..... *per cent* 30
Shrinkage water ..... *per cent* 21.6
Pore water ..... *per cent* 8.4
Modulus of rupture ..... *lbs. per sq. in.* 487.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 249.7
Slaking test, average ..... *min.* 7

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	Trace	.....
40	Trace	.....
60	Trace	.....
80	Trace	.....
120	.02	Quartz and mica particles
200	.07	Quartz and mica particles

Drying shrinkage:—

	Per cent
Linear; wet length	6.6
Linear; dry length	7.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	15.9	Cream	4.95	.....
5	9.6	Darker cream	5.7	.....
9	1.7	Gray	10.1?	Conchoidal vitreous fracture
12	.57	.....	5.6	Conchoidal vitreous fracture
13½	18	Tan exterior; bluestoned interior	4.34	

Fusion test:—It deformed at cone 28.

Summary

The strength of the unburned clay is medium high. Its bonding strength is medium. There is only a trace of residues on the screens. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9. The sample is apparently overburned at cone 13½ although it is thought this appearance may be due to the peculiar shattering of the clay during the firing. It is a refractory clay.

Suggested uses: For refractories, particularly those of a dense character such as crucibles; also architectural terra cotta, stoneware, and sanitary ware.

Sample No. 45 (resampled as No. 1678)
(2 miles east of Grand Chain)

This clay was bored for samples and later resampled as No. 1678. This record applies to sample No. 1678.

It is a clay of medium hardness and a red color. It develops a good plasticity when worked with the addition of a sufficient amount of water. When the plastic clay is squeezed through a die it flows fairly well.

Water of plasticity ..... *per cent* 29.2
Shrinkage water ..... *per cent* 15.8
Pore water ..... *per cent* 13.4
Modulus of rupture ..... *lbs. per sq. in.* 526.6
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 299.5
Slaking test ..... *hours* 2½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	1.0	Brown sandstone
40	Trace	Mica and white sand
60	Trace	Mica and white sand
80	Trace	Mica and white sand
120	30.2	Brown and white sand
150	9.4	Brown and white sand
200	2.0	Brown and white sand

Drying shrinkage, linear.....*per cent* 6.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	36.8	Reddish brown	0.6
06	35.0	Reddish brown	1.1
04	34.9	Reddish brown	2.0
02	35.0	Reddish brown	2.2
1	33.8	Reddish brown	2.5
3	33.5	Reddish brown	2.4
5	34.3	Brown and black	2.2
7	32.7	Brown and black	2.2
9	34.0	Black	1.9

The burned pieces are weak.

Fusion test:—No. 45 deforms at cone 30.
No. 1678 deforms at cone 28.

Summary

This clay has a medium high strength tested alone and a medium bonding strength. This is particularly interesting because the screen test shows the presence of a high content of fine grained sand which does not impair its working properties. The drying shrinkage is medium. It shows a very open burning body at all temperatures with low burning shrinkages. The fusion test indicates a refractory clay.

Such open burning refractory clays having good plasticity and strength are of value used alone or in mixtures in the manufacture of refractory wares.

Sample No. 44 [resampled as No. 1691]
(2 miles east of Grand Chain)

This is a soft clay of a gray color. It develops a fair degree of plasticity.

Water of plasticity .....*per cent* 33.8
Shrinkage water .....*per cent* 21.4
Pore water .....*per cent* 12.4
Modulus of rupture .....*lbs. per sq. in.* 465.6
With 50% standard sand—Modulus of rupture.....*lbs. per sq. in.* 325.6
Slaking test .....*min.* 32

Screen test:—

Mesh	Residue *Per cent*	Character of Residue
20	Trace	.....
40	Trace	Mica
60	Trace	.....

80	Trace	
120	1.32	Mica and sand
150	5.47	Mica and sand
200	4.80	Mica and sand

Drying shrinkage:—

	Per cent
Linear; wet length	6.8
Linear; dry length	7.0

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	31.0	Light gray	1.45
06	27.6	Light gray	2.24
04	23.2	Cream	3.81
02	22.2	Cream	3.6
1	17.2	Cream	4.1
3	17.4	Cream	4.6
5	11.5	Grayish	4.9
7	12.3	Grayish	5.1
9	10.4	Grayish	5.3
11	10.9	Grayish	5.0

Fusion test:—It deforms at cone 29.

Summary

This clay has a medium high bonding strength. The drying shrinkage is medium. It does not reach a low porosity within the temperature range employed—up to cone 11. The shrinkage at cone 9 is medium. It is a refractory clay, but not of high grade. In addition to its use in refractories, it is of the type used for stoneware, architectural terra cotta, and sanitary ware.

Sample No. 17

(River bank at Caledonia)

This is a clay of rather hard and shaly character which seems to contain a considerable quantity of mica. The clay is of a brownish color marked with yellow specks. It has rather a poor degree of plasticity and does not flow satisfactorily through a die.

Water of plasticity	*per cent*	80.9
Shrinkage water	*per cent*	28.1
Pore water	*per cent*	52.8
Modulus of rupture	*lbs. per sq. in.*	180.9
Slaking test, average	*min.*	4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	0.25	Particles of clay
14	2.2	Particles of clay
20	8.8	Particles of clay
35	19.5	Sand and clay
48	6.3	Clay and flakes of mica
65	4.3	Clay and flakes of mica
100	5.0	Clay and flakes of mica
150	4.0	Clay and flakes of mica
200	4.1	Clay and flakes of mica

Drying shrinkage, linear.....*per cent* 5.0
Volume .....*per cent* 25

Burning test:—

Cone	Porosity	Color	Remarks
	Per cent		
02	38.6	Light brown	Poorly oxidized
1	38.2	Light brown	.....
3	38.8	Light brown	.....
5	38.6	Darker brown	.....
7	34.6	Darker brown	.....
9	34.0	Black	Appears to show vitrification
13	14.8	Black	Overburned

Fusion test:—It melts to a glass below cone 26.

Summary

The strength of the clay is medium low. The percentage of screen residue is high. Its drying shrinkage is medium low. It appears to be overburned at cone 13 even though its porosity is still quite high.

The exceptionally high contents of water of plasticity and pore water indicates a very high colloidal content. Because of this the clay gives erratic results in the strength tests. This deposit has proved to be a good grade of fuller's earth and a plant is in operation preparing it for the market.

Sample No. 37a

(Barber farm; sec. 13, T. 15 S., R. 1 E.)

This is a light gray soft clay which contains many mica particles. The plastic mass is readily molded into shape and it flows well through a die.

Water of plasticity .....*per cent* 27.9
Shrinkage water .....*per cent* 14.9
Pore water .....*per cent* 13.0
Modulus of rupture .....*lbs. per sq. in.* 240.7
With 50% standard sand—Modulus of rupture.....*lbs. per sq. in.* 238.7
Slaking test, average .....*min.* 15

Drying shrinkage:—

	Per cent
Linear; wet length	3.2
Linear; dry length	3.4

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		*Per cent*
2	28.80	Cream	2.6
5	27.00	Cream	2.2
9	3.7	Light gray	6.1
12	7.2	Light gray	5.0
13½	13.0	.....	2.4

Fusion test:—Complete fusion at cone 25.

Summary

This clay has medium strength. Its drying shrinkage is medium low. It develops a high degree of vitrification between cones 5 and 9 with a medium burning shrinkage. It overburns at cone 12 and is non-refractory since it fuses at cone 25.

The clay ought to find use for manufactures of stoneware, architectural terra cotta, sanitary ware and similar wares.

ALEXANDER COUNTY

CLAYS FROM THE AETNA POWDER COMPANY'S LAND

Bedded clays are exposed at several places on the land of the Aetna Powder Company. High on the ridge at the first separator house, at least 9 feet of gray laminated clay has been exposed in the excavation for the foundation. The clay is light drab to gray in color and interstratified with distinct beds of mica and fine sand. The section is as follows:

Section at first separator house of Aetna Powder Company at Fayville

		Thickness
		Feet
3.	Loess, with soil at top	20
2.	Gravel	1 to 2
1.	Clay laminated (Sample No. 41); small crystals of gypsum	9

The clay could not be worked while this part of the plant is in operation. Results of tests of sample No. 41, which was taken from the upper 5 feet, are given below.

In the hollow behind the old powder plant, clay is exposed at several places. The section varies from place to place, but the following is representative:

Section behind old powder plant at Fayville

		Thickness	
		Ft.	*In.*
7.	Soil	1	3
6.	Loess	10+	..
5.	Clay and sand, ash colored	4	..
4.	Sand, buff, but loosely cemented	5	6
3.	Conglomerate layers, cemented by iron; pebbles up to 3 inches	1	6
2.	Clay, lignitic	3	..
1.	Clay, sandy, micaceous; very pure in places (Sample No. 42)	4	..

Most of this clay has 20 feet or more of overburden. Results of the tests on Sample No. 42 are given below.

RESULTS OF TESTS

ALEXANDER COUNTY

Sample No. 41

(Aetna Powder Company, at Fayville)

This is a micaceous clay of a gray color streaked with brown. It is moderately hard. When plastic, it is rather sticky.

Water of plasticity	*per cent*	32.3
Shrinkage water	*per cent*	21.9

Pore water ..... *per cent* 10.4
Slaking test, average ..... *min.* 8
Drying shrinkage, linear ..... *per cent* 8.6
Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
02	18.9	Cream	3.9	12.5	Shrinkage determined on very small piece
13	8.4	Gray	3.9	12.5	Vitreous; conchoidal fracture; not overburned; shrinkage determined on very small piece

Fusion test:—⅓ deformed at cone 25. The cone appears to have developed a decided vesicular structure.

Summary

A very plastic and rather sticky clay, which has a medium drying shrinkage. It has a medium porosity at cone 02 and is still quite porous at cone 13 with a medium high shrinkage. Its fusion point is about cone 25, which places it amongst the non-refractory clays.

The incomplete tests indicate a clay which may be suited for stoneware, sanitary ware, or similar wares.

Sample No. 42

(Aetna Powder Company at Fayville)

The clay is a uniform light gray in color. It is rather hard. When tempered with water it has a fair degree of plasticity and flows through a die satisfactorily.
Water of plasticity ..... *per cent* 29.1
Shrinkage water ..... *per cent* 15.4
Pore water ..... *per cent* 13.6
Modulus of rupture ..... *lbs. per sq. in.* 283.1
Slaking test, average ..... *min.* 10
Drying shrinkage, linear 7.5
Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	12.8	Cream	13.7	Hackly fracture, vitreous
5	1.3	Gray	16.0	.....
9	0.0	Gray	17.5	.....
13	0.0	.....	17.5	.....

Fusion test:—Cone down at cone 25. No vesicular structure seems to have been developed in the cone.

Summary

The clay has a medium strength. Its linear shrinkage is medium. The total shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and there are no signs of overburning at cone 13. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, and face-brick.

CLAYS OF PENNSYLVANIAN AGE

Field and Laboratory Notes on Pennsylvanian Clays

Field notes by C. R. Schroyer
Tests by C. W. Parmelee

MONROE COUNTY

Clay outcrops in St. Clair County along a small creek that flows southwest in the SW. ¼ sec. 22, T. 1 S., R. 10 W. The clay is at the base of the Pennsylvanian system, specifically at the Cheltenham horizon. At the outcrop it is mottled yellow and white, plastic, and comparatively free from sand. Borings show that the yellow color is restricted to the upper part where there is an overburden of gravel and glacial drift.

Section of clay 1 mile south of Columbia

		Thickness Ft.	In.
5.	Overburden, clay and gravel	0 to 20	..
4.	Clay, yellow and white (by boring)	10	8
3.	Clay, white, exposed in bank of creek	2	..
2.	Clay; boring in bed of creek (Sample No. 61)	3	6
1.	Limestone, Mississippian	..	..

The slope above the creek has slumped and it is uncertain if this thickness of 16 feet 2 inches represents the maximum thickness of the clay, which is exposed for 320 feet along the stream. A well 28 feet in depth ended in loose sand less than a quarter of a mile east of the outcrop. Other wells which should have reached the clay if it were a persistent bed, have not revealed it elsewhere.

The quantity of this clay, though apparently small, is probably sufficient so that development for use as a blend with other clays might be considered. It is at the horizon of the Cheltenham clay of the St. Louis district. Sample No. 62 was taken from a boring which penetrated the entire thickness.

RESULTS OF TESTS

MONROE COUNTY

Sample No. 61
(1 mile south of Columbia)

This is a medium hard, grayish-colored clay, mottled with dark brown. It has a medium hardness. When tempered with water it becomes very plastic.

Water of plasticity	*per cent*	33.5
Shrinkage water	*per cent*	20.5
Pore water	*per cent*	13
Modulus of rupture, average	*lbs. per sq. in.*	567
minimum	*lbs. per sq. in.*	420
maximum	*lbs. per sq. in.*	773
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	372.7
Slaking test, average	*min.*	16
Drying shrinkage, linear	*per cent*	8.4

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	Trace	.....
35	Trace	.....
60	0.32	Colored sand
120	0.3	Colored sand
200	Trace	Colored sand

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
02	1.5	Tan	7.6	Hackly, vitreous
2	0.6	Tan	7.4	Hackly, vitreous
5	1.6	Tan	6.9	Vitrified, hackly
9	6.1	Tan	6.3	Overburned
13	7.0	Dark tan	5.3	Overburned

Fusion test:—Complete fusion before cone 26.

Summary

This clay has an exceptionally good strength when tested alone, but only medium when mixed with standard sand. It is very free from all particles coarser than 200 mesh. The drying shrinkage is medium. It develops a high degree of vitrification at an exceptionally low temperature and overburns at cone 5. It is completely fused before cone 26 is reached and therefore is a non-refractory clay.

This clay will probably be most useful for the manufacture of brick and blocks, etc., for building purposes, and possibly pavers.

Sample No. 62

(1 mile south of Columbia)

The sample borings are a gray color, mottled with yellow. When mixed with a suitable quantity of water, the clay becomes very plastic.

Water of plasticity	*per cent*	38.9
Shrinkage water	*per cent*	22.9
Pore water	*per cent*	15.9
Slaking test, average	*min.*	8
Drying shrinkage, linear	*per cent*	8.5

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Total shrinkage	Remarks
	Per cent		*Per cent*	*Per cent*	
02	1.5	Terra cotta	3.7	11.2	Vitrified
1	1.8	Light brown	4.0	12.5	Vitrified
5	0.7	Reddish brown	....	....	Vitrified conchoidal fracture
9	5.0	Reddish brown	....	6.5	Overburned
13	8.5	Reddish brown	....	....	Vesicular

Fusion test:—Completely fused at cone 27, vesicular.

Summary

This is a non-refractory clay which vitrifies at a very low temperature and overburns between cones 5 and 9. Its drying shrinkage is medium. Burning shrinkage at cone 1 is high.

It is suited for use in the manufacture of building brick and common wares.

MADISON COUNTY

"The outcrop of the fire clay in Madison County extends from a point on the county line north of Godfrey southerly and easterly to East Alton. South of East Alton it is cut off by the alluvium of the Mississippi River bottom. Fire clay is found, however, two miles east of Collinsville at Cantine at a depth of 270 feet, and it seems probable in view of the extent of the fire clay into the St. Louis district, that it may be found underlying the entire county."[1]

This clay is used for sewer pipe by the East Alton Stoneware Pipe Company at their plant 1½ miles northeast of East Alton.

Section of the Stoneware Pipe Company's shaft at East Alton in the NE. ¼ sec. 15, T. 5 N., R. 9 W.

		Thickness Ft.	Thickness In.
7.	Shale, light colored; flint concretions and nodules of calcareous ironstone	50	..
6.	Shale, black; "slate" of miners	1	6
5.	Coal (No. 2)	2	3
4.	Clay, "little vein"	4	..
3.	Limestone; hard, flinty, brecciated beds	7	..
2.	Fireclay: Green shale—3 in.; Dark shale—2 in.; Coal—1 in.; Light colored fireclay—3 ft. (Sample No. 59); Dark clay, colored by carbon—11 ft. (Sample No. 60)	14	6
1.	Sandstone, brown, below	..	..

Only the upper 2½ to 3 feet of the dark clay and the 3 feet of light clay are used for sewer pipes. The lower beds run high in sulphur and contain large amounts of pyrite. These lower beds are variable in thickness and in places missing, so that the total thickness is not over six feet. At the old mines in the NW. ¼ sec. 15 the thickness is reported to have been about seven feet.

RESULTS OF TESTS

MADISON COUNTY

Sample No. 59

(Stoneware Pipe Company's shaft; NE. ¼ sec. 15, T. 5 N., R. 9 W.)

A very hard, dark gray colored clay which develops a good plasticity although a little sticky. It flows satisfactorily through a die when rather soft.

Water of plasticity .....*per cent* 36.2
Shrinkage water .....*per cent* 24.0

[1]Lines, Edwin H., The Pennsylvanian fire clays of Illinois: Ill. State Geol. Survey Bull. 30, p. 66, 1917.

Pore water ..... *per cent* 12.2
Modulus of rupture ..... *lbs. per sq. in.* 589.0
With 50% standard sand—Modulus of rupture..... *lbs. per sq. in.* 169.8
Slaking test ..... *hours* 6

Screen test:—

Mesh	Residue *Per Cent*	Character of residue
40	.17	Pyrites
60	4.57	Pyrites, hard particles of clay and fine sand
80	1.05	Pyrites, fine sand, and clay
120	6.76	Pyrites, sand, and clay
150	1.4	Pyrites, mica, fine sand, mostly clay
200	1.44	Mica, fine sand and clay

Drying shrinkage:—

	Per cent
Linear; wet length	9.72
Linear; dry length	10.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	3.4	Grayish white	6.3	
5	2.4		6.6	Black core
9	5.4	Tan exterior	5.7	Black core
12	14.2	Red tan exterior, bluestoned interior	3.4	
13	11.9		2.3	
15	10.0	Buff bluestoned	2.9	Large iron slag spots

Oxidation conduct:—Very difficult to oxidize.
Fusion test:—Down at cone 28.

Summary

A clay which has medium high strength when tested without admixture of sand but shows a medium low bonding power. It contains a notable amount of mineral particles which are retained upon the screens. The presence of pyrite amongst these explains the slag spots formed at high temperatures as well as the pitted and vesicular appearance of the fusion test. Undoubtedly this clay can be greatly improved by washing. The drying shrinkage is medium high and the burning shrinkage at cone 9 is medium high. Its low porosity at cone 2 is unusual. The overburning which develops between cones 9 and 12 is undoubtedly due to the high carbon and sulphur content. It is a difficult clay to oxidize.

It is thought that the purification of this clay by washing will greatly improve its properties and extend its usefulness; otherwise, it will be very difficult to use because of its high carbon-sulphur content and consequent slow oxidation.

Sample No. 60

(Stoneware Pipe Company's shaft; N.E. ¼ sec. 15, T. 5 N., R. 9 W.)

The sample is a dark brown clay, having a flinty hardness. Its plasticity is good although it is slightly sticky. When it has rather a soft consistency, it flows well through a die.

Water of plasticity ..... *per cent* 33.05
Shrinkage water ..... *per cent* 23.05
Pore water ..... *per cent* 10.0
Modulus of rupture ..... *lbs. per sq. in.* 427
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 164.5
Slaking test ..... *hours* 5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
60	Trace	Particles of sand
80	Trace	.....
100	0.16	Fine sand
150	0.17	Fine sand and organic matter
200	0.15	Fine sand and organic matter

Drying shrinkage:—

	Per cent
Linear; wet length	8.72
Linear; dry length	9.3

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Total shrinkage *Per cent*	Remarks
2	2.45	Red	7.28	15.5	Vitreous
5	1.5	Grayish	7.3	....	Black core
9	0.7	Gray exterior	7.4	....	Black core
12	2.6	Tan exterior; bluestoned	7.8	....	.....
13	3.8	.....	6.1	....	Overburned

Fusion test:—Cone 31—bloated.

Summary

This clay is similar in some respects to sample No. 59. Its bonding strength is medium low although the pure clay has a considerably higher modulus of rupture. It contains very little material too coarse to pass a 200-mesh sieve. The drying shrinkage is medium high. The burning conduct is of particular interest because of the low porosity reached at a low cone (2) and maintained over a wide range of temperature. There are some slight indications of overburning above cone 12. The presence of a black core at cones 5 and 9 indicates that care will be required in oxidizing this clay during burning.

Suggested uses: Its property of burning dense at a low temperature and maintaining a wide vitrification range ought to make it desirable for vitrified or close bodies. It may possibly serve for pavers although the poor oxidation conduct may prevent this. It is being used for sewer pipe and probably would serve for conduits. The color of the burned clay is not satisfactory for stoneware. It may possibly be used for architectural terra cotta.

CALHOUN COUNTY

Formerly a plant at Golden Eagle manufactured fire brick from the clay lying directly below the No. 2 coal. The mines are in bad condition (fig. 53) and no measurement of the clay could be made. Five feet of the upper part of the seam was mined. At the bottom of this level are nodular limestone boulders full of pyrite crystals. Smaller boulders were found scattered through the clay. The sample No. 58 was taken from a pile of clay which had been dug several years previous. However this clay was still unslacked and appeared fresh and in good condition.

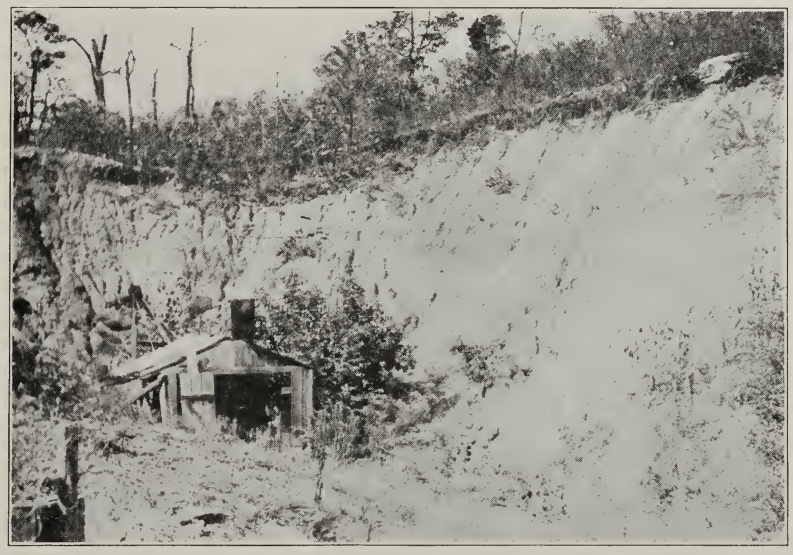


FIG. 53. Abandoned fire clay pit at Golden Eagle.

The area underlain by this clay is small, but with the present equipment might again justify operation. Directly above the clay is a two-foot coal bed which is mined with it. Transportation is entirely by water.

RESULTS OF TESTS

CALHOUN COUNTY

Sample No. 58

(Abandoned plant at Golden Eagle)

This is a very hard grayish colored clay which contains much finely divided pyrite. Upon the addition of a suitable amount of water it develops a good but sticky degree of plasticity. It slakes very slowly.

Water of plasticity	*per cent*	34.4
Shrinkage water	*per cent*	25.5
Pore water	*per cent*	18.9
Modulus of rupture	*lbs. per sq. in.*	165.7
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	124.6
Slaking test	*hours*	5½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
120	.50	Pyrites, fine sand and particles of sand
150	.09	Mica and sand
200	.12	Pyrites, sand, clay and organic material

Drying shrinkage:—

	Per cent
Linear; wet length	10.05
Linear; dry length	11.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	10.0	.....	6.1	.....
5	5.2	Tan	6.0	Small black core
9	7.0	Buff	4.3	Black core, fine iron
12	5.0	Buff exterior; bluestoned	5.0	spots
13	7.0	.....	2.6	Flashed
15	5.5	Buff; bluestoned	2.8	Overburned

Fusion test:—Cone ⅓ deformed at cone 26. The cone has a vesicular structure.

Summary

This clay has a medium low strength and a medium low bonding strength. The drying shrinkage is medium high. The effect of the small residue of finely divided pyrite becomes evident at the higher temperatures, especially in the fusion test. Washing the clay for some products will correct this. The poor oxidation conduct should be noted. The clay is on the border line between a non-refractory and a refractory material. The test piece has the appearance of having been overfired at cone 15.

Suggested uses: Architectural terra cotta, face brick.

GREENE COUNTY

At White Hall, Greene County, fireclay has long been dug for use in the manufacture of sewer pipe, and stoneware and refractory clay has been shipped widely from the pits at Drake.

Two miles southeast of Hillview in the S. ½ sec. 34, T. 12 N., R. 13 W., a small amount of clay has been recovered from above the Mississippian limestone. This is probably a residual clay from the decay of the limestone and if so, does not properly belong in the Pennsylvanian system.

The clay has a greenish or bluish white color when wet, but whitens upon drying. The exposed part contains abundant cherty and calcareous nodules, and gritty calcareous sand. The thickness may locally be as much as 10 feet but the distribution is irregular and pockety, conforming as it does into the irregular surface of the underlying weathered limestone.

Section of the small opening in S. ½ sec. 34, T. 12 N., R. 13 W.

		Thickness *Feet*
4.	Loess and soil	10 ±
3.	Gravel	2
2.	Clay, blue, containing calcareous sand and small gravel; traces of pink (Sample No. 57)	3
1.	Limestone, residual, decomposed, and cherty; covered at base but underlain by bedded limestone further down the ravine	12

The extent of this clay is uncertain, but it has been found in nearby wells to the west. A few carloads have been dug from the slope above the limestone one mile west of this outcrop where a boring is said to have penetrated 9 feet of clay. The results of the tests made on sample No. 57 are given on pages 84 and 85.

The overburden would range from 15 to 35 feet, depending upon how far the working penetrated the divides.

Washing would be necessary to make this clay suitable for use as a refractory.

The results of the tests made on sample No. 55 which is from the E. N. Ford farm near Hillview, are given on pages 85 and 86.

Clay has not been shipped from Drake for over two years. Previous to that time it had been shipped more widely than any other in Illinois. The greatest thickness of clay ever dug was 26 feet. A well penetrated 8 feet of clay below this. As both the top and bottom are irregular, the thickness is variable and becomes as little as 5 feet. An eighth of a mile south of the station it is 20 feet thick.

The overburden varies from 10 to 40 feet, a thickness that makes the working of the old pit unprofitable.

The clay has an Indian red color locally, especially near the top of the west pit, which renders the clay useless for refractory purposes.

Clay is also reported from north of the railroad at Drake, where a well section was given as follows:

Log of well north of Drake

Description of strata	Thickness *Ft.*	Depth *Ft.*
"Earth"	12	12
Not described	8	20
Sandstone	7	27
Clay	15	42
Limestone	..	..

Sample No. 136, sent in by Mr. A. M. Cain, was taken from a shallow pit north of the railroad. Sample No. 54 was taken from the lower clay; sample No. 56 from the upper clay, ¼ mile south of Drake. Sample No. 53 from the farm of C. T. Hicks, ⅛ mile south of Drake. The results of tests on these samples are given on pages 86 to 90.

Section of clay pits east of White Hall

		Thickness Ft.	In.
6.	Soil and yellow underlying hardpan	3	..
5.	Clay, yellow, and till	16	..
4.	Shale and clay, sandy; stringers of gravel	17	5
3.	Clay, buff and white (Sample No. 49)	3	5
2.	Clay, bluish with scattered purplish red and dark stains (Sample No. 52)	7	6
1.	Partly covered to deepest part of pit; clay not now worked	3	6

The clay above as well as that below is used entirely for sewer pipe and stoneware by the White Hall Sewer Pipe and Stoneware Company at their plant in White Hall. Results of tests on samples No. 49 and No. 52 are given on pages 90 to 92.

Section 2½ miles northeast of White Hall

		Thickness Ft.	In.
6.	Drift	12	..
5.	Shale, local	1	10
4.	Coal (No. 2)	2	6
3.	Clay, yellow, sandy	4	..
2.	Clay, white and buff (Sample No. 51)	6	..
1.	Clay, bluish; iron concretions in places; used for sewer pipes (Sample No. 50)	17	6

The results of tests made on samples No. 51 and No. 50 are given on pages 92 to 94. Lines[1] says of this area: "It is reported * * * that good deposits extending another mile east are available when the present pits are worked out. The dip of the rocks here is easterly, and nothing is known of the clay after it gets below drainage, but it is possible that shafts would reach the clay over a large area."

RESULTS OF TESTS

GREENE COUNTY

Sample No. 57

(S. ½ sec. 34, T. 12 N., R. 13 W.)

The sample is a gray colored clay stained with yellow and containing a few black spots. When tempered with water it is very plastic.

Water of plasticity	*per cent*	25.9
Shrinkage water	*per cent*	14.9
Pore water	*per cent*	11.0
Modulus of rupture	*lbs. per sq. in.*	565.5
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	370
Slaking test, average	*min.*	9
Drying shrinkage, linear	*per cent*	7.0
Volume	*per cent*	27.6

[1]Lines, Edwin H., Pennsylvanian fire clays of Illinois: Ill. State Geol. Survey Bull. 30, p. 67, 1914.

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	12.9	Gray	12.5	
1	18.9	Cream	11.1	
3	1.5	Dark gray	12.5	Vitreous conchoidal fracture
5	0.3	Dark gray	13.1	
7	0.4	Dark gray	12.5	Glassy fracture
9	0.6	Dark gray	12.1	Glassy fracture
13	0.6	Dark gray	11.7	Glassy fracture

Small particles of some more fusible mineral are scattered through the mass.
Note:—Grayish color of cone 3 et seq. may be due to reduction.
Fusion Test:—Fused completely at cone 26.

Summary

The strength of the unburned clay is medium high and the bonding strength is medium. The drying shrinkage is medium and at cone 9, the total shrinkage is medium. The test pieces were virtually non-porous at cone 3 and showed no signs of overburning at cone 13, indicating a very long range of vitrification. It is not a refractory clay.

Suggested uses: The very satisfactory strength tests together with the early vitrification and long heat range suggest a clay useful for stoneware, architectural terra cotta, sewer pipe, and paving brick. The rapid rate of vitrification between cones 1 and 3 may prove to limit its usefulness.

Sample No. 55
(E. N. Ford farm, near Hillview)

This clay is colored brown mottled with gray. It contains numerous lumps of limestone varying in size from a small grain to a hazel nut. The clay tempered with water has good plasticity but is slightly sticky if too wet. Its conduct when squeezed through a die is fair.

Water of plasticity ..... *per cent* 39.5
Shrinkage water ..... *per cent* 25.4
Pore water ..... *per cent* 14.1
Modulus of rupture ..... *lbs. per sq. in.* 172.5
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 145.17
Slaking test, average ..... *min.* 55
Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	.25	Light colored particles, few sand grains
60	.97	Light colored particles, few sand grains
80	.23	More fine sand
120	.42	Light particles and fine sand
150	.18	Light and colored
200	.07	Fine sand, mica, light and hard particles

Drying shrinkage:—

	Per cent
Linear; wet length	6.05
Linear; dry length	7.52
Volume	25.0

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	2.19	Very light tan	9.58	.....
5	0.5	Very light tan	9.58	.....
9	3.3	Gray	9.78	Vitreous fracture
12	4.62	Gray with iron spots	8.4	Small light red iron spots slagged in the piece
13	9.0	.....	6.3	.....

Fusion test:—Deforms at cone 29.

Summary

This is a clay of a medium low strength and medium low bonding strength. It has only a slight amount of screen residues coarser than a 200 mesh. The drying shrinkage is medium. It is practically non-absorbent at cone 2 and overburns between cones 5 and 9. The shrinkage at cone 9 is high. Although the test cone did not deform until cone 29 was reached, yet there were numerous slag spots indicating advanced stages of fusion in local areas.

Suggested uses: Face brick, sewer pipe (?), paving brick (?), architectural terra cotta, sanitary ware.

Sample No. 136

(A. M. Cain; near Drake)

This sample is a sandy, hard clay of a light gray color, mottled with brown. It has a medium plasticity and is inclined to be sticky. When forced through a die it flows satisfactorily.

Water of plasticity	*per cent*	25.6
Shrinkage water	*per cent*	14.9
Pore water	*per cent*	10.7
Modulus of rupture	*lbs. per sq. in.*	586
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	376
Slaking test, average	*min.*	28

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	5.31	Quartz particles
40	.39	Quartz particles
60	1.67	Quartz particles
80	.55	Quartz particles, white and brown
120	3.76	Quartz particles
200	2.96	Quartz particles, mostly brown

Drying shrinkage:—

	Per cent
Linear; dry length	9.5
Linear; wet length	10.7
Volume	28.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
04	24.7	Salmon	+0.65
02	25	Red brown	+0.8
2	23.7	Red brown	0.2
5	23	Red brown	1.4
9	20	Chocolate	1.5
13	21	Chocolate	3.1

Fusion test:—Completely deformed at cone 25.

Summary

This clay has a medium high strength, tested alone, but its bonding strength is medium. It contains a considerable amount of quartz sand. The drying shrinkage is medium high. The total shrinkage at cone 9 is medium. The burning shrinkages at all temperatures are low. In fact, there is a slight swelling at temperatures up to cone 1. The clay is open burning since its porosities are high at cones 5 and above. It is non-refractory.

It is suited best for brick and similar products having a dark color and high porosity.

Sample No. 54

(¼ mile south of Drake)

This is a soft clay of a light gray color mottled strongly with darker gray and occasional brown spots. After the addition of a suitable amount of water it develops good plastic properties and flows fairly well through a die.

Water of plasticity	*per cent*	24.5
Shrinkage water	*per cent*	11.7
Pore water	*per cent*	12.8
Modulus of rupture	*lbs. per sq. in.*	250
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	220

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.13	Roots and rock particles
40	0.03	Roots and rock particles
60	0.15	Quartz sand
80	0.03	Quartz sand
120	0.54	Quartz sand, and mica
200	4.2	Quartz sand, and mica

Drying shrinkage:—

	Per cent
Linear; dry length	5.7
Linear; wet length	5.4
Volume	24.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	22	White	..	
1	22	White	..	
3	21	Light cream	2.8	Earthy fracture, vanadium? stain
5	20	Light cream	3.5	
6	19	Light cream	3.9	Earthy fracture, vanadium? stain, slight iron stain
8	16	Dark cream	4.1	Earthy fracture, vanadium? stain, slight iron stain
12	7.6	Cream, bluestoned slightly	5.7	
13	4.0	Light tan exterior, bluestoned	5.8	
15	4.0	Tan exterior, bluestoned	6.9	

Fusion test:—Deforms at cone 29.

Summary

This is a clay having medium bonding strength. The drying shrinkage is medium. It contains very little material coarser than a 200 mesh. The burning shrinkage at cone 8 is medium. Samples burned up to and including cone 8 have quite a high porosity. This decreases rapidly between cones 8 and 12. It is a refractory clay.

Possible uses: Architectural terra cotta, sanitary ware, stoneware, face brick, as a bond clay in refractories.

Sample No. 56

(¼ mile south of Drake)

A medium soft clay colored light gray, with brown stains and containing a few black nodules. When tempered with water it is very plastic and flows well through a die.

Water of plasticity	*per cent*	21.2
Shrinkage water	*per cent*	10.1
Pore water	*per cent*	11.1
Modulus of rupture	*lbs. per sq. in.*	462
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	231.8
Slaking test, average	*min.*	14

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.3	Rootlets and rock particles
40	0.12	Rootlets and quartz grains

60	0.33	Rootlets and white quartz grains
80	0.08	.....
120	3.42	White sand and mica with some organic matter
200	8.59	White sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	19.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
1	23	Cream	2.2	.....
2	20	Cream	2.5	Earthy fracture
3	21.4	Light cream	3.4	Earthy fracture
6	19	Light cream	3.3	Earthy fracture, slight veining of iron stain
9	15	Cream	3.5	Earthy fracture
12	7	Dark cream	4.4	Earthy fracture
13	4	Light tan exterior; bluestoned	4.5	Very minute glassy spots on and in the piece
15	5	Light tan; bluestoned	..	.....

Fusion test;—Cone 28.

Summary

The strength of the dry clay is medium high. Its bonding strength is medium. The amount of residues on the screens is small. The drying shrinkage is medium low and the total shrinkage at cone 9 is medium. It is a refractory clay.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, face brick, refractory wares.

Sample No. 53

(C. T. Hicks; ⅛ mile south of Drake)

This is a hard clay of a light gray color mottled with brown and darker gray color. When tempered with water it develops a good degree of plasticity and may be made to flow satisfactorily through a die.

Water of plasticity .....*per cent* 17.2
Shrinkage water .....*per cent* 8.74
Pore water .....*per cent* 8.51
Modulus of rupture .....*lbs. per sq. in.* 120.2
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 103.1

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.3	Quartz grains, rock grains and roots

40	.09	Quartz grains, rock grains and roots
60	1.0	White sand with darker particles
80	0.4	White sand with darker particles
120	3.8	White sand with darker particles
200	4.6	White sand with darker particles

Drying shrinkage:—

	Per cent
Linear; dry length	4.0
Linear; wet length	3.8
Volume	17.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	26	White	2.4	Earthy fracture
3	23	Very light cream	3.6	Earthy fracture shows vanadium (?) stain
6	22	Very light cream	4.4	Earthly fracture. Iron spots, very small
8	19	Very light cream	4.6	.....
9	18.2	Very light cream	4.9	.....
12	13.0	Very light cream	6.2	.....
13	7.6	Very light cream	6.2	Iron spots, very small and not conspicuous
15	7.0	Bluestoned; tan exterior	7.5	.....

Fusion test:—Deforms at cone 30.

Summary

This clay has a medium low strength and a medium low bonding strength. The amount of the residues left upon the screens is moderate. The drying shrinkage is low. Shrinkage at cone 8 is medium. Vitrification proceeds slowly until cone 13 is reached. It is a refractory clay.

Suggested uses: Face brick, architectural terra cotta, sanitary ware, and refractories.

Sample No. 49

(Clay pit east of White Hall)

This is a light gray colored clay with brown stains which is moderately hard. Good plasticity is developed upon the addition of water, and in this condition it flows readily through a die.

Water of plasticity ..... *per cent* 24.3
Shrinkage water ..... *per cent* 11.2
Pore water ..... *per cent* 13.1
Modulus of rupture ..... *lbs. per sq. in.* 369.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 189.5
Slaking test, average ..... *min.* 23

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	0.46	Colored sand
40	0.37	Colored sand
60	1.94	Colored sand
80	0.54	Colored sand
120	0.13	Colored sand
200	Trace	Colored sand

Drying shrinkage:—

	Per cent
Linear; wet length	4.75
Linear; dry length	4.98
Volume	21.2

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
2	22.8	Cream	7.2	
3	18.4	Light cream	7.2	Smooth fracture; very fine iron speck
6	16.5	Cream	7.2	Smooth fracture; very fine iron speck
8	12.9	Cream	5.8	
9	9.6	Cream	5.6	Smooth fracture, very fine iron speck
12	0.5	Gray interior; light tan exterior	7.0	
13	1.01		6.5	
15	8.8	Bluestoned; buff exterior	6.0	Very small iron spots

Fusion test:—It fused at cone 30.

Summary

The clay has a medium strength and medium low bonding strength. The amount of screen residues is slight. The drying shrinkage is medium low and the burning shrinkage at cone 9 is medium. The clay vitrifies to a porosity of less than one per-cent between cones 9 and 12. Overburning appears at about cone 15.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, refractories.

Sample No. 52

(Clay pit east of White Hall)

This is a hard dark gray colored clay mottled with yellowish brown. When ground and tempered with water it develops a good plasticity and flows readily through a die.

Water of plasticity ..... *per cent* 23.0
Shrinkage water ..... *per cent* 9.9
Pore water ..... *per cent* 13.1
Modulus of rupture ..... *lbs. per sq. in.* 380.2
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 243.9
Slaking test, average ..... *min.* 10
Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	.....
35	0.12	Particles of shale, coal and sand
48	0.10	Particles of shale, coal and sand
65	0.15	Particles of shale, coal and sand
100	2.0	Particles of shale, coal and sand with much mica
150	3.8	Particles of shale, coal and sand with much mica
200	8.1	Particles of shale, coal and sand with much mica

Drying shrinkage:—

	Per cent
Linear; dry length	5.0
Volume	18.5

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	21.6	Light tan	9.1	.....
1	15.7	Light tan	10.4	.....
3	10.6	Tan	10.1	.....
5	7.2	Gray[1]	10.4	Semi vitreous fracture
8	2.5	Gray[1]	11.3	Vitreous luster
13	1.6	Gray	11.0	Vitreous luster, conchoidal fracture

Fusion test:—Fused completely at cone 26.

Summary

The clay has a medium strength and a medium bonding strength. The screen residues are considerable. The drying shrinkage is medium low. The total shrinkage at cone 8 is medium. The clay is well vitrified at cone 8 and is not overburned at cone 13. It is non-refractory.

Suggested uses: Stoneware, sanitary ware, architectural terra cotta, face brick.

Sample No. 51

(2½ miles northeast of White Hall)

This is a rather hard clay of a dark brown color and good plasticity. Its conduct when squeezed through a die is fair.

Water of plasticity .....*per cent* 24.0
Shrinkage water .....*per cent* 14.1

[1]Grayish color may be due to reduction.

Pore water ..... *per cent* 9.9
Modulus of rupture ..... *lbs. per sq. in.* 446.8
With 50% standard sand—Modulus of rupture..... *lbs. per sq. in.* 199
Slaking test, average ..... *min.* 11
Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	.....
60	Trace	.....
80	Trace	.....
120	0.18	Colored sand
200	1.4	White sand and mica

Drying shrinkage:—

	Per cent
Linear; dry length	6.4
Linear; wet length	6 0
Volume	27.8

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	19.	White	4.8	.....
3	16.2	Light cream	5.3	Smooth, fine grain fracture
6	13.5	Light cream	5.3	Smooth fracture, nearly vitreous
8½	9.8	Cream	5.8	Smooth fracture, nearly vitreous
9	9.5	Cream	6.1	Smooth fracture, nearly vitreous
12	1.1	Stoneware gray, uniform	7.6	Smooth fracture
13	0.5	Stoneware gray, uniform	7.6	Smooth fracture

Soluble salts:—Pieces burned at cone 02 give a strong yellow surface discoloration after being soaked in water.
Fusion test:—Deforms at cone 31.

Summary

The strength of the raw clay is medium high. The bonding strength is medium low. The percentage of screen residues is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Clay is well vitrified at cone 12. It is a refractory clay.

Suggested uses: Refractories, stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 50

(2½ miles northeast of White Hall)

This clay is of a dark gray color with some portions brown and other reddish. It is quite hard but a good plasticity is developed when it is mixed with water and properly worked. Its conduct when flowing through a die is fair.

Water of plasticity ..... *per cent* 22.4
Shrinkage water ..... *per cent* 10 6
Pore water ..... *per cent* 11.8

Modulus of rupture .....*lbs. per sq. in.* 207
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 275.5
Slaking test, average .....*min.* 11
Screen test:—

Mesh	Residue	Character of residue
	Per cent	
40	Trace	Quartz particles
60	0.38	Quartz particles
80	Trace	.....
120	1.57	Mica and quartz sand
200	4.7	Mica and quartz sand

Drying shrinkage:—

	Per cent
Linear; dry length	5.9
Volume	21.8

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
04	28.6	Light tan, pinkish	0.13	.....
02	25.1	Cream, pinkish	1.5	.....
2	20.6	Light tan	3.1	Very fine iron spots
5	20.1	Tan	3.3	.....
9	13.1	Stoneware gray	4.6	Smooth fracture
13	10.8	Stoneware gray	4.5	.....

Fusion test:—It fused completely at cone 26.

Summary

The strength of the dry clay is medium. The bonding strength is medium. The quantity of screen residue is small. The shrinkage at cone 9 is medium. It is a non-refractory clay.

Suggested uses: It is reported as being used for sewer pipe. It appears adapted for stoneware, architectural terra cotta, sanitary ware, and face brick.

SCOTT COUNTY

The clay at Alsey underlies 5 feet of cherty limestone, above which there are 28 to 34 inches of coal. Between these is a 2- to 3-foot thickness of dark, shaly clay. Only the upper part of the lower clay is dug, as the lower beds contain much pyrite. Almost the entire output of the plant had come to be fire brick when it closed in February, 1918, though formerly only building brick was made.

Production ran about 20,000 bricks per day but enlargement of the plant insures a possibility of double that quantity.

The United States Bureau of Standards reports above the signature of A. V. Bleininger, "In the fusion test, conducted in an electric furnace, the softening point of the fire brick was found to correspond to cone 31½, or approximately 3083 degrees F. From this it appears that the fire clay may be considered of No. 1 grade."

Sample No. 71 was taken from the stock pile of the clay used for fire brick and No. 70 from the clay which overlies the limestone. Results of tests are given on pages 96 and 97.

The Cheltenham clay is exposed in the bluff of Mauvais Terre Creek half a mile west of Exeter. The section varies in short distances, and the clay is stained yellow by iron along seams where water circulates. Gypsum crystals may be seen on the weathered surface. This clay was used several years ago by potteries at Exeter and Merritt.

Section along Mauvais Terre Creek half a mile west of Exeter

		Thickness Ft.	In.
8.	Limestone; weathers to rounded boulders, some of large size. Hard; fossiliferous	3	10
7.	Clay, yellow and impure	2	10
6.	Clay, dark blue	3	10
5.	Clay, drab yellow irony seams, gypsum crystals; the lower 4 feet sandy and not included in sample; probably high in sulphur and iron	12	6
4.	Clay, somewhat colored by carbon	..	8
3.	Coal and coaly shale	1	0 to 6
2.	Conglomerate, sandy; pebbles up to the size of a walnut	2	0 to 6
1.	Limestone, Mississippian; cuts out both conglomerate and coal nearby	..	..

Sample No. 65, reported on pages 97 and 98, includes No. 6 and part of 5 of the section.

Section at small coal opening on Mauvais Terre Creek about 4½ miles downstream from Exeter

		Thickness Ft.	In.
8.	Clay shale	4	..
7.	"Slate" or carbonaceous shale	2	..
6.	Coal (No. 2)	2	8
5.	Covered	5	4
4.	Limestone, nodular; same as number 8 of previous section	4	6
3.	Clay, impure, stained yellow	3	6
2.	Limestone, regular bedded, with shale partings	8	8
1.	Clay	unmeasured	

At outcrops two miles northeast of Alsey numerous gypsum crystals appear on the surface of four feet of clay just below the limestone.[1]

If conditions here are similar to those at Alsey, the fire clay might be expected to be of better quality east of the outcrop where it would lie at a greater depth. The record of the city well at Jacksonville, Morgan County, shows five feet of fire clay below a coal at a depth of 148 feet.

Near Franklin six feet of fire clay is reported at a depth of 347 feet.

[1]Op. cit., p. 68.

RESULTS OF TESTS

SCOTT COUNTY

Sample No. 71

(Abandoned plant at Alsey)

The sample is a hard material of a dark gray color. When tempered with water it becomes very plastic. Its conduct in flowing through a die is fair.

Water of plasticity ..... *per cent* 21.8
Shrinkage water ..... *per cent* 10.9
Pore water ..... *per cent* 10.9
Modulus of rupture ..... *lbs. per sq. in.* 328
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 144
Slaking test, average ..... *min.* 10

Screen test:—

Mesh	Residue *Per cent*
20	0.6
40	0.13
60	0.11
80	0.14
120	Trace
200	Trace

Drying shrinkage:—

	Per cent
Linear; dry length	5.9
Linear; wet length	5.6
Volume	21.4

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	16	Cream	7.1	Vanadium stain (?)
3	15	Light cream	5.3	Vanadium stain (?)
5	14	Light cream	6.0	.....
6	12.7	Light cream	6.0	.....
8	11.2	Light cream	....	.....
9	10	Cream	6.6	.....
12	....	Bluestoned; light buff outside	9	Contains fine black specks
13	1.0	Bluestoned	....	.....
15	3.4	Buff exterior; bluestoned (black)	8.9	.....

Fusion test:—It deforms between cones 30 and 31.

Summary

The clay has a medium strength and a medium low bonding strength. The amount of screen residues is slight. Drying shrinkage is medium and total shrinkage at cone 9 is medium high. It is practically non-porous at cone 13 and apparently shows slight overburning at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, refractories.

Sample No. 70

(Abandoned plant at Alsey)

This is a grayish colored clay of medium hardness. It is very plastic when tempered with water.

Water of plasticity ..... *per cent* 41.8
Shrinkage water ..... *per cent* 31.4
Pore water ..... *per cent* 10.4
Modulus of rupture ..... *lbs. per sq. in.* 609
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 302.8
Slaking test, average ..... *min.* 7
Drying shrinkage, linear ..... *per cent* 12.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	Trace	Hard lumps of black shale
14	Trace	Hard lumps of black shale
20	0.85	Hard lumps of black shale with particles of coal
35	6.8	
48	7.4	
65	7.4	
100	5.1	
150	8.1	
200	8.5	

Burning te t —

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	20	Yellow cream	2.9	Hackly fracture
02	18	Dark cream	4.7	Hackly fracture
2	7.5	Buff cream	6.2	Hackly fracture
5	3.5	Buff cream	5.9	Hackly fracture
9	2.5	Gray; bluestoned	6.8	Hackly fracture
13	10	Light tan; bluestoned	5.6	Black core
14	9		21.5	Bloated

Fusion test:—It fuses at cone 26. Vesicular structure.

Summary

The clay has a medium high strength and medium bonding strength. The drying shrinkage is high. The total shrinkage at cone 9 is high. It is fairly well vitrified at cone 2 and is overburned at cone 13. The oxidation rate is slow.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 65

(Bluff of Mauvais Terre Creek ½ mile west of Exeter)

This is a brownish colored shaly clay. It becomes very plastic when tempered with water. It flows satisfactorily through a die.

Water of plasticity	*per cent*	22.0
Shrinkage water	*per cent*	9.9
Pore water	*per cent*	12.0
Modulus of rupture	*lbs. per sq. in.*	240.8
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.22	Colored sand
40	0.40	
60	0.77	
80	0.64	
120	2.9	
200	2.3	

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	18.7

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24	Pinkish cream	3.1	
1	24	Pinkish cream	3.1	
3	22	Medium cream	3.8	Fine iron specks, earthy fracture
5	21	Medium cream	4.0	
6	21	Medium cream	4.2	Fine iron specks; earthy fracture
9	17	Light tan	4.3	Numerous fine iron specks
12	9	Darker tan	6.2	Numerous fine iron specks
13	3.5	Bluestoned	6.6	
15	3.3	Buff exterior; bluestoned (black)	6.7	Iron spots

Fusion test:—It deforms between cones 26 and 27.

Summary

This clay has a medium strength and a medium low drying shrinkage. The total shrinkage at cone 9 is medium. It is well vitrified at cone 13 and not overburned at cone 15. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, for which uses it should be washed, face brick.

PIKE COUNTY

Clay outcrops in the west bluff of Illinois River at Bedford. The relation to the Mississippian limestone at the north suggests faulting. Twenty-seven feet of clay are exposed above and 16 or more feet below. This thickness makes the deposit of special interest.

Section of the river bluff at Bedford

		Thickness Ft.	In.
7.	Loess and loose limestone blocks to top of mound	50	..
6.	Covered, cherty fragments over slope	10	..
5.	Clay, bluish gray; partly covered yellow iron stains in lower part (Sample No. 67)	27	..
4.	Covered interval	11	6
3.	Partly covered, probably clay	9	..
2.	Clay, blue (Sample No. 69)	16	6
1.	Partly covered to water level in Illinois River; loose blocks indicate Mississippian limestone in the lower part of this interval	20	..

Clay has been dug in small amounts about 2 miles north of Pittsfield and used as a blend for surface clay in making building brick and drain tile and possibly also for pottery. This deposit (sample No. 66, p. 101) is reported to vary from 6 to 13 feet in thickness. It is of a bluish white color where exposed and has an overburden of drift and loess up to 20 feet in thickness. Boring has shown that the clay extends back under the bluff over an area of several acres and the topography suggests that extensive areas are underlain by clay both to the south and east.

RESULTS OF TESTS—PIKE COUNTY

Sample No. 67

(West bluff of Illinois River at Bedford)

This is a gray colored, soft clay which develops a good plasticity.

Water of plasticity	*per cent*	26.5
Shrinkage water	*per cent*	12.5
Pore water	*per cent*	14.0
Modulus of rupture	*lbs. per sq. in.*	303.8
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	248.7
Slaking test, average	*min.*	15

Screen test:—

Mesh	Residue Per cent	Character of residue
40	0.12	Quartz sand, and pyrite
60	0.4	Quartz sand, and pyrite
80	Trace	.....
120	0.3	Sand and some pyrite
200	0.3	Sand and some pyrite

Drying shrinkage:—

	Per cent
Linear; dry length	6.4
Linear; wet length	6.0
Volume	23.9

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
04	25.4	Terra cotta	2.1	
02	16.6	Light red brown	4.8	
2	6.7	Brown	7.4	Hackly fracture
5	2	Brown-red	5.6	Vitreous, appears to be overburned
9	2.7	Brown-red	...	Overburned badly

Fusion test:—It fused to glass at cone 25.

Summary

The clay has a medium strength and a medium bonding strength. The drying shrinkage is medium. The total shrinkage at cone 5 is medium low. At cone 9 the sample is overburned. It is a non-refractory clay.

Suggested uses: Face brick, sewer pipe, hollow block, paving brick (?).

Sample No. 69

(West bluff of Illinois River at Bedford)

This is a clay of a uniform gray color, containing some shaly particles. It is very plastic when tempered with water. The flowing conduct of the clay when forced through a die is satisfactory.

Water of plasticity ..... *per cent* 24.7
Shrinkage water ..... *per cent* 13.5
Pore water ..... *per cent* 11.2
Modulus of rupture ..... *lbs. per sq. in.* 498.3
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 242.0
Slaking test, average ..... *min.* 14

Screen test:—

Mesh	Residue
	Per cent
20	None
40	Trace
60	0.3
80	Trace
120	0.2
200	0.2

Drying shrinkage:—

	Per cent
Linear; dry length	6.6
Volume	26

Burning test:—

Cone	Porosity	Color	Burning shrinkage	Remarks
	Per cent		*Per cent*	
04	26.5	Terra cotta	4.8	Hackly fracture
02	14.4	Terra cotta	4.9	Hackly fracture
2	1.8	Reddish brown	7.6	Hackly fracture
5	24	Reddish brown	...	Overburned
9	19.9	Red-brown	...	Swelled

Fusion test:—Bloated and fell over before cone 8 in a Fletcher furnace.

Summary

This clay has a medium high strength, a medium bonding strength, and a medium drying shrinkage. The total shrinkage at cone 2 is medium; vitrification proceeds rapidly and is practically complete at cone 2. It is overburned at cone 5.

Suggested uses: Common brick, drain tile.

Sample No. 66

(2 miles north of Pittsfield)

This is a soft clay, colored yellow to dark brown. A fair degree of plasticity may be developed.

Water of plasticity ..... *per cent* 27
Shrinkage water ..... *per cent* 13.5
Pore water ..... *per cent* 13.5
Modulus of rupture ..... *lbs. per sq. in.* 414.5
Slaking test, average ..... *min.* 11

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.08	Rock particles and organic matter
40	Trace	.....
60	Trace	.....
80	Trace	.....
120	0.79	White sand and rootlets
200	1.32	White sand and rootlets

Drying shrinkage:—

	Per cent
Linear; dry length	8.2
Volume	24.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	17	Cream	4.9	.....
2	14	Cream	5.1	.....
3	12	Medium cream	5.8	Smooth fracture; fine iron specks (?); none on another trial piece
6	6	Medium cream	6.2	Smooth fracture; fine iron specks (?); none on another trial piece Somewhat conchoidal fracture
9	1.2	Stoneware gray	6.3	Vitreous

12	1.0	Gray white	5.0	Fine veining of iron stain; good color
13	1.6	Gray white	4.5	.....
15	3.8	Gray white	4.5	Fine iron spots

Fusion test:—It deformed at cone 29.

Summary

The sample is a clay of medium high strength which has a medium drying shrinkage. The total shrinkage at cone 9 is medium high. Vitrification is practically complete between cones 6 and 9. There are some indications of overburning at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, a plastic bond for refractories.

ADAMS COUNTY

Toward the west the basal clays of the Pennsylvanian contain more gypsum, and are generally streaked by yellowish and buff iron markings. In a road cut 2½ miles north and one mile west of Camp Point, 8½ feet of distinctly bedded clay are exposed. The upper 2½ feet are tough, ash colored clay, containing much gypsum sand and small gypsum crystals, and colored by streakings of iron. An overburden of from 5 to 15 feet of gravel and clayey till with locally thin sandstone layers immediately above the clay, forms the covering.

BROWN COUNTY

On Crooked Creek in the vicinity of Ripley, clay has been dug for stoneware. The old pits one mile south of Ripley are almost obliterated by surface wash and caving. Since the clay directly underlies the drift it does not promise to be of refractory value.

SCHUYLER COUNTY

At a small mill and kilns at Frederick, drain tile is manufactured from a mixture of surface clay and bedded Coal Measures clay.

Section of the clay pit at Frederick

		Thickness	
		Ft.	*In.*
5.	Loess	9	..
4.	"Potter's clay"	8	..
3.	Coal ("peacock vein")	3	3
2.	Clay, drab and sandy; plant remains and yellow iron stains	10	..
1.	Shale, blue	..	..

MC DONOUGH COUNTY

"The line of outcrop of the clay in McDonough County extends along the bluffs and ravines of the east fork of Crooked Creek from Bardolph to the county line on the north side and Tennessee on the south side, whence it extends southeast toward Schuyler County."[1] Clay is being dug about

[1]Op. cit., p. 70.

Colchester and from a pit about 3 miles northeast of Macomb.

At the open pit of the Macomb Sewer Pipe Works about 3 miles northeast of Macomb the clay is stripped, loaded by steam shovel, and hauled over a standard gauge track to the plant at Macomb. Samples No. 73a, No. 73b, and No. 73c are respectively from the top, middle and bottom of a boring on the Company's property. Results of tests are given on pages 105 and 106. A section of the face of the pit is as follows:

Section of the face of the pit of the Macomb Sewer Pipe Works, 3 miles northeast of Macomb

		Thickness *Feet*
6.	Loess, drift, and soil	20 to 25
5.	Sandstone, hard, and chert	6
4.	Coal traces	..
3.	Clay, used for sewer pipe	10
2.	Pebbles and iron concretions in layer	..
1.	Shale, dark blue	10+

The Colchester Brick and Tile Company uses the clay from this horizon at its plant near Colchester in the manufacture of refractory brick, tile, and silo blocks. The clay is dug from an open pit in the side of a hollow (fig. 54) and hauled by wagon to the mill.

Section of Colchester Brick and Tile Company's pit, half a mile north of Colchester

		Thickness *Ft.*	*In.*
7.	Shale, sandy	20	..
6.	Shale, dark, and coal	2	..
5.	Fireclay, poor grade	3	..
4.	Shale, dark	..	6
3.	Fireclay, stained yellow by iron (Sample No. 75a)	6	..
2.	Shale	7	..
1.	Fireclay (Sample No. 75b)	10	..

Sample No. 75a is from No. 3, and sample No. 75b from No. 1 of the above section. Results of tests are given on pages 106 to 108.

Most of the clay obtained about Colchester is taken from mines west of town. The clay taken from the shaft of the Gates Fireclay Company is used for making flue linings among other clay products.

Log of shaft at the Gates Fireclay Company's mine, near Colchester

Description of strata	Thickness *Feet*	Depth *Feet*
Soil and glacial clay	24	24
"Soapstone," compact shale	26	50
Coal (No. 2)	2½	52½
Fireclay, used in the manufacture of flue linings, etc., "upper vein" (Sample No. 88, see pages 108-109)	5½	58

Log of Gates Fireclay Company's mine shaft—Continued

Limestone, scattered boulders	..	..
"Hard rock," probably sandstone	6	64
Clay, "middle vein"	8	72
Sandstone	5	77
Shale	8	85

The firm of Baird Brothers is operating a mine one mile northwest of Colchester in a 7- to 8-foot bed of clay that lies below the "middle vein" of the Gates shaft. On the Valentine farm three drift tunnels have been opened into a 7- to 8-foot bed of clay, and about 150 tons are taken out

FIG. 54. View of the Colchester Brick and Tile Company's pit half a mile north of Colchester showing No. 2 coal near the top and stoneware clay at the base.

per day. One hundred and twenty acres of the adjoining Forncuff farm are underlain by the lower and upper clay. The middle clay contains so many boulders that it cannot be worked profitably. The clay is hauled by steam locomotive over a tram to tipple at the Chicago, Burlington and Quincy Railroad at Colchester.

Sample No. 74 (p. 109) is from south mine, and sample No. 78 (p. 110) from the north mine on the Valentine farm. Sample No. 75 (p. 111) was taken from a carload of clay as it came from the Meyers mine, west of the Baird mines.

Two other mines were being operated in June, 1918; one 3 miles west of town in the same bed as are the above mines, another 2½ miles west where the No. 2 coal and the underlying clay are both recovered.

RESULTS OF TESTS

MC DONOUGH COUNTY

Sample No. 73-a

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

The sample is a gray shaly material, containing many mica flakes. It becomes very plastic when worked with water.

Water of plasticity ..... *per cent* 28.3
Shrinkage water ..... *per cent* 12.9
Pore water ..... *per cent* 15.4
Modulus of rupture ..... *lbs. per sq. in.* 352.2
Slaking test, average ..... *min.* 13
Drying shrinkage:—

	Per cent
Linear; dry length	6.5
Volume	22.9

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*
1	16	Cream	10.6
5	10	Cream	12.4
9	4.8	Light gray	13.1
15	2.1	Light gray	10.0

Fusion test:—Cone slightly deformed at cone 26. Vesicular at cone 27.

Summary

The clay has a medium strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. It has a low porosity at cone 9 and has only a slight porosity at cone 15. It is non-refractory.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 73-b

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

This is a rather hard clay, varying in color from a light to a dark gray. When tempered with water it becomes very plastic and flows satisfactorily through a die.

Water of plasticity ..... *per cent* 24.9
Shrinkage water ..... *per cent* 11.9
Pore water ..... *per cent* 13.0
Modulus of rupture ..... *lbs. per sq. in.* 356.5
Slaking test, average ..... *min.* 9
Drying shrinkage:—

	Per cent
Linear	6.2
Volume	21.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
1	10.9	Light brown	13.7	Poorly oxidized
5	5.1	Brown	14.0	.....
9	0.4	Dark brown	12.5	.....
15	0.0	Dark gray	11.2	Overburned, beginning to bloat

Fusion test:—At cone 26 the cone was deformed half way and showed many bubbles on the surface.

Summary

The strength is medium. The drying shrinkage is medium. Burning shrinkage at cone 9 is medium. It burns to a dense body at cone 5 and is practically non-porous at cone 9. At cone 15, signs of overburning appear. It is non-refractory.

Suggested uses: Sewer pipe, face brick, possibly paving brick.

Sample No. 73-c

(Macomb Sewer Pipe Works; 3 miles northeast of Macomb)

This is a hard dark gray-colored clay which develops a very good plasticity.

Water of plasticity ..... *per cent* 26.8
Shrinkage water ..... *per cent* 10.5
Pore water ..... *per cent* 16.3
Modulus of rupture ..... *lbs. per sq. in.* 339.3
Slaking test, average ..... *min.* 9
Drying shrinkage:—

	Per cent
Linear	7.0
Volume	16.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
1	11.2	Cream	12.5	
5	4.0	Cream	14.4	Conchoidal vitreous fracture
9	0.2	Gray	14.4	Conchoidal vitreous fracture
15	0.8	Gray	11.2	Conchoidal vitreous fracture

Fusion test:—⅓ deformed at cone 27. Vesicular.

Summary

The clay has a medium strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. It attains a low porosity at cone 5 and is completely vitrified between that and cone 9. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, face brick, sanitary ware, and some types of refractories.

Sample No. 75-a

(Colchester Brick and Tile Company's pit; ½ mile north of Colchester)

This is a clay which is not of a uniform color, varying from gray to yellowish brown. The gray portions are harder than the yellow. Tempered with water, it develops a medium plasticity. When squeezed through a die, it flows rather badly.

Water of plasticity ..... *per cent* 25
Shrinkage water ..... *per cent* 7.6
Pore water ..... *per cent* 17.3
Modulus of rupture ..... *lbs. per sq. in.* 269.6
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 192
Slaking test, average ..... *min.* 4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.2	White and colored sand
60	1.4	White and colored sand
80	0.3	White and colored sand
120	3.3	White and colored sand and mica
200	3.7	White and colored sand and mica

Drying shrinkage:—

	Per cent
Linear; dry length	4.7
Linear; wet length	4.5
Volume	11.2

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	33	Light red	1.0	
02	30	Light red	1.7	
5	23.3	Dark tan	4.4	Hackly fracture
9	13.5	Brown	8.2	Hackly fracture
13	16.9		...	Overburned

Fusion test:—It fused completely at cone 26.

Summary

The clay has a medium strength, a medium low bonding strength, a medium low drying shrinkage, and a medium high total shrinkage at cone 9. Minimum porosity—13.5%—is attained at cone 9 and overburning appears at cone 13. It is a non-refractory clay.

Suggested uses: Brick, tile.

Sample No. 75-b

(Colchester Brick and Tile Company's pit; ½ mile north of Colchester)

This is a hard gray-colored clay, having an irregular fracture. When tempered with water, it develops a good plasticity and flows well through a die.

Water of plasticity ..... *per cent* 20.0
Shrinkage water ..... *per cent* 8.6
Pore water ..... *per cent* 11.4
Modulus of rupture ..... *lbs. per sq. in.* 263
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 199.6
Slaking test, average ..... *min.* 8

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.3	Rock particles
40	0.9	Rock particles and quartz sand
60	2.1	Rock particles and quartz sand
80	0.3	Rock particles and quartz sand
120	1.4	Quartz sand and mica
200	2.2	Quartz sand and mica

Drying shrinkage:—

	Per cent
Linear	4.8
Volume	16.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	30	White	0.1	
02	28	Cream	0.5	
2	25.5	Cream	1.7	Hackly fracture
5	25.0	Cream	2.0	Hackly fracture
9	17.4	Gray white	3.0	A very few fine iron spots
13	6.3	Stoneware gray	5.2	Many slagged iron spots
14	6.8	Buff	2.7	

Fusion test:—Completely deformed at cone 26. Not fused as much as 75-a.

Summary

The strength of the clay is medium. Its bonding strength is medium. The drying shrinkage is medium low and total shrinkage at cone 9 is medium. The porosity is low at cone 14 but vitrification is incomplete. It is a non-refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick.

Sample No. 88

(Gates Fireclay Company's mine, near Colchester)

This is a dark colored, very hard clay, which becomes very plastic when tempered with water.

Water of plasticity	*per cent*	27.7
Shrinkage water	*per cent*	11.7
Pore water	*per cent*	15.9
Modulus of rupture	*lbs. per sq. in.*	496
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	243
Slaking test, average	*min.*	14

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	None	
40	Traces	
60	0.29	Dark red grains
80	0.2	
120	2.8	
200	1.0	

Drying shrinkage:—

	Per cent
Linear; dry length	7.2
Linear; wet length	6.7
Volume	28

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	0.8	Tan	7.7	Vitreous fracture
2	0.6	Darker tan	7.6	Vitreous fracture
3	0.5	Grayish tan	7.3	Vitreous fracture
4	0.7	Grayish tan	6.9	Vitreous fracture
6	0.8	Dark gray	6.9	Vitreous fracture
9	2.6	Stoneware gray	7.3	Numerous fine iron spots; vitreous fracture
12	4.4	Bluestoned, surface flashed	4.0	Numerous fine iron spots; vitreous fracture
13	2.2	Buff exterior	2.6	Many fine iron spots; blue core

Fusion test:—Partly deformed at cone 27.

Summary

The strength of the unburned clay is medium and its bonding strength is medium. The amount of residue on the sieve is low. The drying shrinkage is medium and the total shrinkage when burned at cone 9 is medium high. It is practically non-porous at cone 01 which is an unusually low temperature and shows distinct over-burning at cone 13. The sample burned at that temperature appears to be reduced. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, refractories (particularly when good bonding properties are required), sanitary ware, face brick.

Sample No. 74

(Valentine farm, south mine; near Colchester)

This is a dark gray colored clay which becomes very plastic upon the addition of water.

Water of plasticity ..... *per cent* 22.0
Shrinkage water ..... *per cent* 8.0
Pore water ..... *per cent* 14.0
Modulus of rupture ..... *lbs. per sq. in.* 221.8
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 214.9

Screen test:—

The sample would not slake satisfactorily for this test.

Slaking test, average ..... *min.* 8

Drying shrinkage:—

	Per cent
Linear; dry length	4.8
Linear; wet length	4.6
Volume	15.0

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
1	21	Cream	2.2	.....
2	20	Cream	2.3	.....

3	20	Cream	2.3	Fine iron speck
6	17.9	Slightly darker	3.2	Fine iron speck
9	13.4	Cream	3.5	Fine iron speck
12	9.0	Cream	4.0	Numerous quartz grains; fine iron spots
13	4.1	Buff	4.4	Iron spots, small; slagged
15	3.9	Bluestoned; buff exterior	4.3	Slagged iron spots

Fusion test:—Cone half way down at cone 26.

Summary

The clay has a medium strength and medium bonding strength. Drying shrinkage is medium low and total shrinkage at cone 9 is medium. It is non-refractory.

Weathering or aging will improve its working properties.

Suggested uses: Face brick, stoneware, and terra cotta. But its slow slaking character as noted under the screen test may limit its usefulness for the latter purposes.

Sample No. 78

(Valentine farm, north mine; near Colchester)

This is a hard dark gray colored clay which may be brought to a very plastic condition. Its conduct when flowing through a die is very good.

Water of plasticity ..... *per cent* 19.
Shrinkage water ..... *per cent* 9.4
Pore water ..... *per cent* 9.6
Modulus of rupture ..... *lbs. per sq. in.* 325.8
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 209.4
Slaking test, average ..... *min.* 7

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.8	Hard clay and rock particles
40	0.7	Hard clay and rock particles, also pyrite
60	0.7	Hard clay and rock particles, also pyrite
80	0.22	Hard clay and rock particles, also pyrite
120	0.75	Hard clay and sand
200	0.7	Hard clay and sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.1
Linear; wet length	4.0
Volume	16.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	23	Cream white	2.8	Granular fracture
1	23	Cream white	2.6	Granular fracture
3	20	Cream white	3.3	Granular fracture
6	18	Cream white	4.0	Granular fracture
8	18	Cream	...	Granular fracture

9	14.9	Cream	4.0	
12	9.0	Dark cream or light tan	5.2	Earthy fracture. Numerous fine iron specks. Also quartz grains.
15	6.5	Buff exterior; bluestoned	7.2	Numerous iron spots. Slagged.

Fusion test:—No deformation at cone 25. It deforms at cone 29.

Summary

The strength of the unburned clay is medium. Its bonding strength is medium. The drying shrinkage is medium low. The total shrinkage at cone 9 is medium. A low porosity is not reached until cone 15. It is a refractory clay.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, refractories, and face brick.

Sample No. 75

(Meyers mine; near Colchester)

This is a very hard dark gray clay which slakes very slowly. However, when properly worked with sufficient water, it develops a fair degree of plasticity and may be forced through a die satisfactorily.

Water of plasticity ..... *per cent* 20.7
Shrinkage water ..... *per cent* 9.1
Pore water ..... *per cent* 11.6
Modulus of rupture ..... *lbs. per sq. in.* 295.6
Slaking test, average ..... *min.* 8
Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	17.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	20	Cream	2.8	
2	17.3	Cream	4.7	
5	13.8	Cream	8.3	
9	6.8	Cream	11.0	Fine iron spots
12	2.5	Gray white	11.5	Fine iron spots
13	1.5	Grayish white	10.5	Numerous iron spots, small
15	4.0	Grayish white	....	Numerous iron spots; slagged

Fusion test:—No deformation at cone 30. No vesicular structure.

Note:—The iron (?) spots are so black as to suggest the presence of manganese. Its unusual appearance may be due to reduction. The effect at higher cones is very unique and interesting.

Summary

The clay has a medium strength. The drying shrinkage is medium low. Total shrinkage at cone 9 is medium high. Minimum porosity. Complete vitrification is

reached at cone 13. At cone 15 the slight increase in porosity may indicate incipient overburning. It is a refractory clay.

Suggested uses: The appearance of numerous fine slagged spots at the high temperatures raises a question as to the desirability of this as a material for refractories. Its slow slaking character lessens its value in some degree for stoneware and architectural terra cotta. However, weathering or aging will correct these difficulties.

FULTON COUNTY

A sample of clay (No. 84) from about a mile northwest of Avon was taken at the Avon Milling and Manufacturing Company's plant at Avon. The clay had been dug from the bed of Swan Creek and is used for refractory linings about the boiler.

RESULTS OF TESTS

FULTON COUNTY

Sample No. 84

(Avon Milling and Manufacturing Company, at Avon)

The clay is a dark gray color with darker patches due to the presence of carbonaceous matter. Its plasticity is only fair and its conduct in flowing through a die is fair.

Water of plasticity ..... *per cent* 21.5
Shrinkage water ..... *per cent* 9.0
Pore water ..... *per cent* 12.4
Modulus of rupture ..... *lbs. per sq. in.* 214
Slaking test, average ..... *min.* 4½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.5	Sand and coal
60	3.2	Sand and coal
80	0.4	Sand and coal
120	2.3	Sand and coal
200	11.6	White sand, mica, and coal

Drying shrinkage:—

	Per cent
Linear; wet length	3.7
Linear; dry length	3.8
Volume	17

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	26	Light tan	1.8	Granular fracture
3	26	Light tan	1.9	Granular fracture
6	25	Light tan	2.6	Granular fracture
9	20	Light tan	3.7	Granular fracture
13	11.6	Buff	5.5	Fine iron (?) spots
15	16.6	Buff	5.8	Fine iron (?) spots

Fusion test:—The cone fused to a glass at cone 28.

Summary

The strength of the clay is medium. There is a considerable amount of residue left on the screens. The drying shrinkage is medium low, and when burned at cone 9, the total shrinkage is medium low. Vitrification is incomplete at cone 13 and it is overburned at cone 15. It is a non-refractory clay.

Suggested uses: Architectural terra cotta, face brick. It appears to be rather short for stoneware.

MERCER COUNTY

The Northwestern Clay Manufacturing Company formerly recovered small amounts of clay with the No. 1 coal at their pits near Griffin. A sample was taken from clay which had been drawn from below the No. 1 coal at that time. The shale, till, and overlying soil are used for sewer pipe.

Section of the Northwestern Clay Manufacturing Company's pit at Griffin

		Thickness *Ft.*	*In.*
6	Soil and yellow clay	10	..
5.	Shale (Sample No. 86)	25 to 30	..
4.	Limestone	2	..
3.	"Potter's clay," thin horizon	unmeasured	
2.	Coal (No. 1)	2	5
1.	Clay (Sample No. 85)	6	..

RESULTS OF TESTS

MERCER COUNTY

Sample No. 86

(Northwestern Clay Manufacturing Company's pit, at Griffin)

The material is a hard grayish-colored, shaly clay, streaked with brown and black. The plasticity is fair.

Water of plasticity	*per cent*	29.5
Shrinkage water	*per cent*	21.9
Pore water	*per cent*	7.6
Modulus of rupture	*lbs. per sq. in.*	190.2
Slaking test, average	*min.*	6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	2.2	Particles of shale, grains of coal
14	1.7	
20	2.4	
35	3.2	
48	0.6	
65	0.4	
100	1.1	
150	1.0	Shale with mica
200	1.5	Shale with mica

Drying shrinkage:—

	Per cent
Linear; dry length	3.62
Linear; wet length	3.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	18.4	Dark red	5.0	Hackly fracture
5	14.5	Dark red	8.5	.....
9	0.5	Dark red	9.4	Vitreous fracture
12	....	.....	...	Bloated

Fusion test:—It fused completely at cone 27.

Summary

The drying shrinkage is medium low. The strength is medium low. The total shrinkage at cone 9 is medium high. The shale reaches a minimum porosity at or before cone 9 and overburns beyond that point.

Suggested uses: Sewer pipe, brick, tile, etc.

Sample No. 85

(Northwestern Clay Manufacturing Company's pit, at Griffin)

The sample is a soft clay of a gray color with darker mottling. Its plasticity is very good when tempered with water.

Water of plasticity .....*per cent* 28.8
Shrinkage water .....*per cent* 11.9
Pore water .....*per cent* 17.0
Modulus of rupture .....*lbs. per sq. in.* 386.7
Slaking test, average .....*min.* 4½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	7.0	Particles of coal and shale
14	6.5	
20	8.9	
35	13.8	
48	3.7	
65	5.4	
100	3.9	
150	2.4	Particles of coal and shale, with flakes of mica
200	2.6	

Drying shrinkage, linear .....*per cent* 6.5
Volume .....*per cent* 21

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	14.4	Cream	13.4	.....
1	6.7	Cream	14.6	.....
3	0.5	Gray	15.9	Vitrified
5	0.8	Dark gray	16.2	Bluestoned
7	1.2	Dark gray	13.6	Bluestoned; slightly vesicular
9	1.4	Dark gray	11.1	Bluestoned; slightly vesicular
13	1.6	Dark gray	7.5	Bluestoned; slightly vesicular

Fusion test:—Completely deformed at cone 26. Vesicular.

Summary

The strength of the clay is medium. The quantity of screen residues is high. The drying shrinkage is medium. The total shrinkage at cone 5 is medium high. Complete vitrification is attained at a very low cone and the incipient overburning which seems to appear at cone 9 does not become serious even at cone 16. The appearance of the pieces suggests reducing conditions during the burn. The appearance of a whitewash on the pieces burned at cone 7 or lower should be noted. It is non-refractory.

Possible uses: Architectural terra cotta, paving brick, stoneware, sanitary ware, sewerpipe, conduits.

ROCK ISLAND COUNTY

A sample was taken from the clay above No. 1 coal at Sears (sample No. 83). The clay below that coal was covered by water when visited. A second sample was taken from white clay lying directly below the No. 1 coal (sample No. 81); ordinarily a 5-foot sandstone commonly separates this clay and the coal but here it is missing. The clay[1] is full of pyrite concretions which weather to limonite at the surface. The plant which formerly operated here is now idle and the pits are in bad condition.

Results of tests on samples No. 83 and No. 81 are given on pages 115 and 116.

A large part of the upper 40 feet of the overburden which is a fine loess of pure quartz sand is now used for moulding sand. The value of the overburden in this case would materially reduce the cost of obtaining the clay if it were to be worked from an open cut. The maximum overburden would be nearly 60 feet.

At Carbon Cliff the fine clay (Cheltenham) varies from 10 to 25 feet in thickness, being replaced where the lesser thickness is found by as much as 10 feet of black shale which apparently wedges out laterally into the clay. The clay shows iron stains and traces of red. At its base there is a layer of nodular impure limestone boulders and limonite concretions. The overburden of 18 to 25 feet could be removed most economically, it is believed, by a steam shovel.

Sample No. 79 was taken from the west bank and sample No. 80 from the working face in the east pit. Results of tests are on page 117.

RESULTS OF TESTS

ROCK ISLAND COUNTY

Sample No. 83

(Clay above No. 1 coal at Sears)

This is a medium hard clay which is colored gray, heavily mottled with brown. The plasticity is very good when it is tempered with water and it flows satisfactorily through a die.

Water of plasticity	*per cent*	28.7
Shrinkage water	*per cent*	16.4
Pore water	*per cent*	12.2

[1]According to Lines, Op. cit., this clay was formerly used for sewer pipe.

Modulus of rupture, maximum .....*lbs. per sq. in.* 768
minimum .....*lbs. per sq. in.* 664
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 329
Slaking test, average .....*min.* 11½
Drying shrinkage:—

	Per cent
Linear; dry length	7.5
Linear; wet length	7.0
Volume	31.2

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	28.0	Pinkish red	1.0	
02	15.0	Pinkish tan	5.1	Hackly fracture
2	1.1		6.7	Hackly fracture
5	2.2	Dark tan	6.8	Glossy fracture
9	1.6	Dark tan	6.5	Smooth vitreous fracture
13	12.0	Gray	4.5	Overburned

Fusion test:—It entirely fused at cone 27.

Summary

The strength of the clay is medium high and its bonding strength is medium. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification proceeds very rapidly between cones 02 and 2, at which temperature it is practically complete. It is overburned between cones 9 and 13. It is non-refractory.

Suggested uses: Face brick, paving brick, sewer pipe, drain tile. The color of the burned material is rather dark for stoneware or terra cotta.

Sample No. 81

(Clay below No. 1 coal at Sears)

This is a soft gray colored clay, streaked with brown and containing a few black spots. It contains much mica.

Water of plasticity .....*per cent* 22.6
Shrinkage water .....*per cent* 9.8
Pore water .....*per cent* 12.7
Slaking test, average .....*min.* 8
Drying shrinkage:—

	Per cent
Linear	5.2
Volume	17.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
1	13.7	Brown	8.7	
5	6.1	Dark brown	11.8	
9	2.4	Dark brown	11.2	
15	...	....	....	Bloated badly

Fusion test:—Completely fused at cone 26 to brown glass showing a partly vesicular structure.

Summary

The drying shrinkage is medium low and vitrification is practically complete at cone 9. It is overburned between that cone and cone 15. It is non-refractory.

Suggested uses: Brick, tile.

Sample No. 79

(West bank at Carbon Cliff)

This is a soft clay having a dark gray color with some brown streaks. When tempered with water it becomes very plastic. It flows fairly well through a die.

Water of plasticity ..... *per cent* 21.7
Shrinkage water ..... *per cent* 8.9
Pore water ..... *per cent* 12.5
Modulus of rupture ..... *lbs. per sq. in.* 287.3
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 119.5
Slaking test, average ..... *min.* 4

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	.....
40	Trace	.....
60	Trace	.....
80	Trace	.....
120	Trace	.....
200	1.8	Sand and mica

Drying shrinkage:—

	Per cent
Linear; dry length	6.6
Linear; wet length	6.2
Volume	17.4

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	32	Cream	0.0	.....
02	32	Cream	1.0	Hackly fracture
2	28	Cream	1.5	Hackly fracture
5	28	Cream	2.0	Hackly fracture
9	23	Cream	3.1	Hackly fracture
13	18	Cream	3.6	Granular fracture
14	6	Brown exterior; bluestoned	2.8	.....

Fusion test:—It fuses entirely at cone 26. No vesicular structure.

Summary

The clay has a medium strength and a medium low bonding strength. The drying shrinkage is medium and the total shrinkage at cone 9 is medium. The clay is very open burning until cone 14 is reached. It is non-refractory.

Suggested uses: Architectural terra cotta, stoneware, sanitary ware, and face brick.

Sample No. 80

(East pit at Carbon Cliff)

This is a clay of a medium degree of hardness, colored gray with a darker mottling. It develops a good degree of plasticity when tempered with water and flows satisfactorily through a die.

Water of plasticity	*per cent*	20.5
Shrinkage water	*per cent*	9.2
Pore water	*per cent*	11.3
Modulus of rupture	*lbs. per sq. in.*	445.4
Slaking test, average	*min.*	10½
Drying shrinkage, linear	*per cent*	6.2
Volume	*per cent*	17.7

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	20.7	Cream	7.2	.....
1	19.7	Cream	7.5	.....
3	16.4	Cream	8.1	Hackly fracture
5	13.4	Gray	8.6	Hackly fracture
8	10.4	Gray	10.0	.....
9	7.2	Gray	9.8	Vitrified; hackly fracture
13	7.5	Gray	9.7	Conchoidal fracture

Fusion test:—Test pieces are ⅔ deformed at cone 26 and slightly vesicular.

Summary

The clay has a medium high strength and medium shrinkage at cone 9. The total shrinkage is medium. Vitrification is still incomplete at cone 13. The clay borders on the refractory type.

Suggested uses: Stoneware, architectural terra cotta, refractories, face brick.

LA SALLE COUNTY

At the pits of the Utica Firebrick and Clay Company two miles south of Utica the section is variable, but a somewhat generalized section of the east pit (fig. 55) is as follows:

Sections of the east pits of the Utica Firebrick and Clay Company 2 miles south of Utica

		Thickness *Ft.*	*In.*
6.	Overburden, glacial drift and soil	12	..
5.	Coal (No. 1)	1	6
4.	Clay, blue, "Joliet clay" (Sample No. 87, p. 125); the upper foot contains numerous pyrite concretions, and similar concretions are found in the lower beds	3	6
3.	Clay, green	..	8
2.	Clay, gray, jointed (Sample No. 77, p. 126); used for fire brick; the upper 3 feet has a few small pyrite seams and concretions (av. 8 ft.); at one place 2 feet of the residual basal clay is lighter in color grading into a darker clay above	4	10
1.	Sandstone, St. Peter; forms the "nigger heads" of the mines; the surface of the sandstone is very uneven and in one place rises so that the clay is only 1½ feet thick	..	..

A second section of East pit of the Utica Firebrick and Clay Company

		Thickness Feet
3.	Soil and drift	2 to 5
2.	Clay, dark gray, with scattered pebbles and some conglomerate	10±
1.	Conglomerate, highly weathered, heavy	..

Sample No. 82 from the east pit was lost in transit, and H. E. Culver of the Survey staff visited the pit later with the intention of taking a sub-

FIG. 55. View of the Utica Firebrick and Clay Company's pit south of Utica; No. 2 coal overlies the clay.

stitute sample. Being unable to find the exact location from which sample No. 82 had been taken, he measured the following section and took sample No. C 82; results of tests are given on pages 126 and 127.

Section of West pit of the Utica Firebrick and Clay Company, near Utica

4.	Overburden, soil and drift	2 to 5
3.	Clay, gray, yellow when first exposed, very tough	2 to 3
2.	Clay, darker yellow, "putty clay" (Sample No. 82); chert concretions and pyrite at base	5 to 6
1.	Sandstone; very much hardened by iron at surface	..

The clay is hauled by train from the pit to a tipple, dumped down onto a tram at river level, transferred across the Illinois River by barge and then taken by train to the plant at Utica.

About 20 acres has been tested by drilling beyond the borders of the present pits.

The plant can produce from 12,000 to 20,000 fire brick per day and about 30 tons of ground fireclay is shipped every month as well as crude clay in varying amounts up to 1000 tons. Small lots of the yellow "putty" clay have been shipped for ochre but most of it is used as furnace lining. A boring between the two pits has shown that the "putty" clay overlies the better grade blue clay.

M. J. Gorman and Company are operating an open pit in sec. 21, T. 22 N., R. 1 E. The clay is hauled 1½ miles by team and wagon to Utica. The average production is about 10,000 tons per year, including both "putty" and blue clay.

Section of M. J. Gorman and Company's pit 1½ miles south of Utica

		Thickness	
		Ft.	*In.*
9.	Soil	1	..
8.	Soil and drift	6	..
7.	Coal (No. 2), absent over parts of the clay	3	..
6.	Clay, yellow and blue, very plastic, scattered gypsum crystals; "putty clay" (Sample No. 97, pp. 127-128)	4	..
5.	Clay, green	..	6
4.	Clay, blue (Sample No. 100, pp. 128-129)	9	..
3.	Pyrite, large boulders, usually with calcareous centers	..	..
2.	Clay, blue	5	..
1.	Sandstone, probably St. Peter	..	..

Sample No. 98 was taken from the side of a gully a few rods up-stream from the mouth of the clay pit. It lies, however, below the mouth of the pit in altitude. This is not worked, and the sample was taken from a 2′ x 4′ x 3″ cut on the sloping surface of the clay bank which lies beneath soil and above sandstone which is probably St. Peter, but may be the lower sandstone of the Pennsylvanian. See page 129 for results of tests.

More than seventy acres of clay have been proved by boring.

The Company is contemplating tractor and trailer haulage over the 1½ miles of paved road to the railroad at Utica.

The Illinois Clay Products Company are producing 250 to 300 tons of ground fireclay per day, from their mine at Deer Park.

Only the upper 6 or 7 feet is mined at the present time, as it is found impracticable to mine a greater thickness.

Section of Illinois Clay Products Company's mine at Deer Park

		Thickness Ft.	In.
10.	Overburden, of glacial till and soil	unmeasured	
9.	"Soapstone," compact, sandy clay shale	15±	..
8.	Coal (No. 2); forms roof of mine	3	6
7.	Clay (Sample No. 93, p. 130); only the upper 6 to 7 feet mined at present; erratic lenses of sandrock at the bottom of the present workings; pyrite nodules about 3 feet from the top of the clay, also large pisolitic boulders; in part of mine, clay rests on St. Peter sandstone and possibly in other part on "Trenton" limestone	13	..
	Outside the mouth of the mine lower beds are exposed as follows:		
6.	Sandstone, thin layer	..	3
5.	Clay, coal and coaly shale (No. 1 [?])	..	6
4.	Fireclay, very fine textured, plastic, and light in color (Sample No. 96, p. 131)	4	..
3.	Fireclay, sandy	2	..
2.	Pyrite bed, less than	..	2
1.	Limestone, Trenton	..	..

The clay is hauled by train and electric motor to the mill and after grinding is carried by cable train across the Big Vermilion River to the Rock Island Railroad.

At Lowell the clay below the No. 2 coal has been used in a small way for pottery at the Lowell Stoneware Company's plant.

Section of the Lowell Stoneware Company's pit at Lowell

		Thickness Feet
4.	Overburden, drift and soil	1 to 12
3.	Coal (No. 2)	3½
2.	Clay (Sample No. 90, p. 132), dark gray to light drab "W" clay; the upper three feet contains much pyrite at the base of which there are locally traces of green coloring	12 to 25
1.	Limestone, Trenton	..

Preliminary drilling is said to have proved that the clay underlies at least 200 acres. A great part of this is overlain by an overburden of less than 15 feet and could easily be removed by steam shovel.

Near the river bank small quantities of clay have been dug from directly beneath 1 to 7 feet of soil and drift overburden. The clay here is distinctly bedded and of a gray color with an occasional yellow pocket. It is sold as the "R" clay (sample No. 89, p. 132).

The Pennsylvanian rocks are missing on the east flank of the La Salle anticline at Utica. The bluffs of Illinois Valley are largely St. Peter sandstone from Utica to Twin Bluffs on the south side of Illinois River. At Twin Bluffs the National Fireproofing Company is working clay in open cut from directly above the St. Peter sandstone, and about a mile to the east the

Herrick Clay Manufacturing Company is tunneling the clay (sample No. 95, p. 133) from the same horizon. A section of the face of the former pit is given here:

Section of National Fireproofing Company's pit at Twin Bluffs

		Thickness Ft.	In.
5.	Overburden, drift	unmeasured	
4.	Shale ("Soapstone")	8	..
3.	Coal (No. 2)	1	11
2	Shale, black	..	6
1.	Clay (Sample No. 94, p. 134); lighter in color and more sandy toward the bottom	7	..

At the Herrick mine the clay is 8 feet thick and because of the eastward dip the overlying shale has increased to more than 30 feet. At the National Fireproofing pit the drift overburden and the shale are used for drain tile and building blocks. The coal above the clay is also recovered. At both plants the clays are ground and shipped. The output from the National Fireproofing plant is approximately 800 tons per week and a similar or somewhat lesser quantity is shipped from the Herrick mine.

At Ottawa the Fox and Illinois rivers have cut through the Pennsylvanian and are now flowing on St. Peter sandstone. About 2 miles east of that city basal Pennsylvanian clay is dug from two open pits; that of the Chicago Retort and Firebrick Company and that of the National Fireproofing Company.

Section of the National Fireproofing Company's "Pioneer" pit 2 miles east of Ottawa

		Thickness Ft.	In.
10.	Soil	..	6
9.	Shale ("soapstone")	16	..
8.	Coal	2	2
7.	Fireclay, dark	1	..
6.	Fireclay, lighter gray (Sample No. 91, p. 135); lenses of large rounded pisolitic boulders which contain large amounts of pyrite	8	..
5.	Clay, green, in lenses, local	..	2
4.	Sandstone, hard, brown	1 to 4	..
3.	Clay, very light in color (Sample No. 92, p. 136)	5 to 9	..
2.	Clay, sandy	1	..
1.	Sandstone, St. Peter	..	..

The clay is dug by steam shovel and hauled by electric tram to the plant at Ottawa. The output is about 5000 tons of manufactured ware per month, chiefly hollow ware and fire brick, and 1000 tons of ground fireclay.

Section of the Chicago Retort and Firebrick Company's pit northeast of Ottawa

		Thickness Ft.	In.
8.	Soil	1	..
7.	Shale, blue, weathers light; "soapstone"	17	..
6.	Shale, darker; colored by carbon	2	..
5.	Coal	2	..
4.	Gypsum, persistent layer	..	1
3.	Clay, colored by carbon	..	2
2.	Fireclay (Sample No. 101, p. 136); traces of green in lower beds where clay becomes lighter in color; large rounded sandy pyritic boulders in bottom of pit; smaller pyrite concretions scattered in the clay	4 to 8	..
1.	Sandstone, St. Peter	..	..

This section differs little from the preceding one, except that instead of the lower clay it has the green clay resting directly upon the St. Peter sandstone. A large area of this clay has been removed, but the Company reports holdings of 300 acres of tested reserve clay land east and north of the present pit. No use is made of the overburden which is removed by steam shovel and tram.

Three grades of clay are used: (1) Raw clay from this pit; (2) raw clay blended with Missouri flint clay; and (3) raw clay blended with a mixture of raw and calcined Missouri flint clay.

About half a mile southeast of Dayton, clay is mined from a tunnel driven in the side of a deep ravine.

Section at Dayton Clay Works half a mile south of Dayton

		Thickness Feet
6.	Loam, drift, and soil	6
5.	Shale, more compact toward the base	32
4.	Shale, dark blue	1
3.	Coal (No. 2)	2±
2.	Clay, sandy, pyritic gray (Sample No. 99, p. 138)	4½ to 5½
1.	Sandstone	..

Sample No. 102 (p. 138) was from an outcrop of the gray fireclay above.

The clay is ground and loaded by elevated conveyor onto a switch of the Chicago, Burlington and Quincy Railroad about 100 yards east of the plant.

The Chicago Firebrick Company is reopening the entries of the old Spicer Coal Company's mine 2 miles east of Marseilles with the intention of obtaining the clay which here is at a depth of about 90 feet. The clay is worked from a new face at the outer margin of the former mine by the room and pillar system.

Section of Chicago Firebrick Company's shaft 2 miles east of Marseilles

		Thickness Feet
	Shaft from top of coal to surface	90±
4.	Coal (No. 2)	2½
3.	Fireclay, drab, comparatively free from pyrite but colored by carbon	3½ to 6
2.	Clay, green; rich in pyrite	½ to 3
1.	Fireclay; pyrite in small crystals to bottom of present workings; a maximum of 12 feet of this lower clay has been penetrated; at the shaft the St. Peter sandstone is 8 feet 4 inches below the bottom of the coal	5

The clay is shipped as ground clay.

Sample No. 129 was taken from the working face omitting the green clay. (See page 140).

South and east from Utica, or away from the crest of the La Salle anticline, the base of the Pennsylvanian beds lowers and in only a few places have mine shafts penetrated to the level of the clay.

Two miles south of Streator, the shaft of the Streator Clay Manufacturing Company penetrates the No. 2 coal, but the underlying clay is not of as good a quality as that farther north.

Section of Streator Clay Manufacturing Company's shaft 2 miles south of Streator

		Thickness Ft.	In.
	Shaft	230	..
4.	Coal (No. 2)	2	6
3.	Fireclay, gray and blue (Sample No. 130-a, p. 140)	1⅓ to 4	..
2.	Clay, sandy, "sandrock"	3 to 5	..
1.	Clay, greenish gray; "Intermediate clay" (Sample No. 130-b, p. 140)	2	6

Bottom not reached.

At Kangley the Spring Lake Coal Company is mining the No. 2 coal. Clay brought out in lifts from digging sumps was sampled from the dump. Results of tests on the sample (No. 131) are given in page 140.

Section of the Spring Lake Coal Company's shaft at Kangley 4 miles northwest of Streator

		Thickness Feet
	Shaft	200
2.	Coal (No. 2)	3
1.	Clay (Sample No. 131); bluish and greenish gray with small gypsum crystals and an occasional iron stain	5

Bottom not reached.

RESULTS OF TESTS
LA SALLE COUNTY

Sample No. 87
(East pit of the Utica Firebrick and Clay Company;
2 miles south of Utica)

This clay is of medium hardness. It is of a dark gray or slate color speckled with a few black spots. The plasticity is very high when it is tempered with water, and its conduct when flowing through a die is good.

Water of plasticity ..... *per cent* 25.6
Shrinkage water ..... *per cent* 17.0
Pore water ..... *per cent* 8.6
Modulus of rupture ..... *lbs. per sq. in.* 497.6
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 290.3
Slaking test, average ..... *min.* 10.5

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	None	.....
40	Trace	.....
60	0.4	Fine white sand
80	0.2	Fine white sand
120	0.7	Fine white sand
200	0.9	Fine white sand

Drying shrinkage:—

	Per cent
Linear; dry length	9.3
Linear; wet length	8.5
Volume	34.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	17.0	Cream, nearly white	3.1	.....
2	12.3	Light cream	4.2	Fine iron spot
4	10.7	White exterior	...	Fine iron spot
8	8.4	Cream	5.1	Numerous fine iron spots
9	8.2	Cream	5.1	Numerous fine iron spots
12	4.7	Bluestoned; cream	5.8	Numerous fine iron spots
14	5.0	Dark buff; bluestoned	5.6	Numerous fine iron spots, slagged

Oxidation conduct:—Appears to be very slow.
Fusion test:—Deforms at cone 28.

Summary

The strength of the raw clay is medium high and its bonding strength is high. The amount of residue on the sieves is slight. The drying shrinkage is medium and the total shrinkage at cone 9 is medium high. Vitrification is incomplete at cone 14. Oxidation appears to have been very slow. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, face brick, refractories.

Sample No. 77

(East pit of the Utica Firebrick and Clay Company; 2 miles south of Utica)

This is a very hard dark gray colored clay. When powdered and tempered with water, it develops a fair degree of plasticity and will flow through a die satisfactorily.

Water of plasticity ..... *per cent* 19.8
Shrinkage water ..... *per cent* 9.3
Pore water ..... *per cent* 10.5
Modulus of rupture ..... *lbs. per sq. in.* 320
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 261
Slaking tests, average ..... *min.* 9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.1	Quartz and pyrite
40	0.2	
60	1.0	
120	1.8	
200	1.2	

Drying shrinkage:—

	Per cent
Linear; dry length	7.5
Linear; wet length	7.0
Volume	19.2

Drying conduct:—Efflorescence, i. e., "whitewash," appears at the corners of the sample.

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	14.4	Cream	4.4	Granular fracture
3	11.0	Cream	4.8	Granular fracture
6	8.5	Darker cream	5.4	Granular fracture
8	5.1	Grayish	5.5	Granular fracture
9	4.4	Grayish	5.1	.....
12	6.0	Bluestoned	4.3	.....
12½	...	Tan, light bluestoned	...	.....
15	5.0	Buff exterior; bluestoned, black	3.6	Some iron spots

Fusion test:—Cone ⅓ deformed at cone 28. Vesicular structure.

Summary

The clay has a medium strength and a medium bonding strength. The drying shrinkage is medium and at cone 9 the total shrinkage is medium high. The clay attains a fairly low degree of porosity at cone 6 and is not overburned at cone 15. It is a refractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, refractories, face brick.

Sample No. C82

(West pit of the Utica Firebrick and Clay Company, near Utica)

This sample was a mixture of a light colored material, which was very hard, and a soft yellow mass. When tempered with water it developed a very good plasticity and could be squeezed through a die satisfactorily.

Water of plasticity ..... *per cent* 32
Shrinkage water ..... *per cent* 16.9
Pore water ..... *per cent* 15.1
Modulus of rupture ..... *lbs. per sq. in.* 484.8
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 185.2
Slaking test, average ..... *min.* 9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	7.8	Sand, colored rock fragments
14	3.5	Sand, colored rock fragments
20	3.5	Sand, colored rock fragments
35	1.3	Sand, colored rock fragments, and coal
48	Trace	Sand, colored rock fragments, and coal
65	1.0	Sand, colored rock fragments, and coal
100	Trace	.....
150	Trace	.....
200	Trace	.....

Drying shrinkage:—

	Per cent
Linear	6.8

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
02	33.7	Reddish cream	1.8	.....
1	3.9	Dark gray	12.7	Very brittle
3	2.2	Dark gray	13.6	Very brittle
5	1.0	Dark brown	12.5	Bloated. Sample heated above this cone was melted.

Fusion test:—Complete fusion at cone 26. Cone shows vesicular structure, but not very decided.

Summary

The strength of the clay is medium high. Its bonding strength is medium low. The drying shrinkage is medium. Total shrinkage at cone 5 is medium high. It appears bloated as though overburned at cone 5. The clay is non-refractory.

Suggested uses: Common brick and tile.

Sample No. 97

(M. J. Gorman and Company's pit; 1½ miles south of Utica)

The following tests relate to the sample collected by Mr. Culver.

The material is of a medium hard shaly nature. With it is mixed a softer portion. The color is dark gray and brown. A good plasticity may be developed. When forced through a die, the clay flows rather badly.

Water of plasticity ..... *per cent* 35.6
Shrinkage water ..... *per cent* 22.9
Pore water ..... *per cent* 12.5
Modulus of rupture ..... *lbs. per sq. in.* 565
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 201
Slaking test, average ..... *min.* 60

Screen test:—

Mesh	Residue *Per cent*
20	0.3
40	17.3
60	17.6
80	6.0
120	0.8
150	1.8
200	4.0

Drying shrinkage:—

	Per cent
Linear; dry length	10.5
Linear: wet length	9

Drying conduct:—Shows tendency to warp.

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	30	Salmon	1.6
06	27	Buff	2.2
04	24	Cream	3.1
02	23	Buff	4.0
1	22	Buff	4.6
2	16	Stoneware	5.4
4	9.5	Gray	5.7
7	5.6	Gray	5.2
9	6.5	Gray	5.5
10	4.4	Gray with brown specks	5.3

Fusion test:—It fused at cone 28.

Summary

The strength of the clay is medium high. Its bonding strength is medium. The total percentage of residue on the screens is high. The drying shrinkage is medium high at cone 9. The total shrinkage is high. The vitrification proceeds slowly and is incomplete at cone 10. It is a refractory clay.

Suggested uses: Refractories, face brick.

Sample No. 100

(M. J. Gorman and Company's pit; 1½ miles south of Utica)

Resampled by Mr. Culver.

The clay is a very hard gray colored material. Its conduct when forced through a die is good.

Water of plasticity ..... *per cent* 24.6
Shrinkage water ..... *per cent* 13.8
Pore water ..... *per cent* 10.8
Modulus of rupture ..... *lbs. per sq. in.* 475
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 222
Slaking test, resample ..... *min.* 40

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.2	Fragments of rock and pyrites
40	0.06	Sand and pyrites
60	3.5	Sand, particles of clay and pyrites
80	2.1	.....
120	14.1	Particles of clay
150	3.4	Particles of clay
200	6.5	Particles of clay

The sample did not slake completely.

Drying shrinkage:—Linear; wet length.....*per cent* 7.3

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	24	Light gray	2.1
06	23	Buff and cream	2.5
04	20	Dark cream	3.3
02	18	Dark cream	4.0
1	16	Dark cream	4.4
3	12	Gray	5.0
5	8	Gray with iron speckles	5.5
7	6	.....	5.5
9	6	.....	5.5
11	7	Brown	5.7

Fusion test:—It deformed at cone 31.

Summary

The strength of the clay is medium high. Its bonding strength is medium. The amount of screen residues is high. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is incomplete at cone 11. It is a refractory clay.

Suggested uses: Refractories, face brick. The slow slaking properties may limit its usefulness for terra cotta, stoneware, and sanitary ware.

Sample No. 98

(Side of gully near M. J. Gorman and Company's pit, near Utica)

This report relates to sample obtained by Mr. Culver.

This is a soft clay, yellow in color and marked with brown spots. When tempered with water, it has good plasticity.

Water of plasticity .....*per cent* 28
Shrinkage water .....*per cent* 12.7
Pore water .....*per cent* 15.3
Modulus of rupture .....*lbs. per sq. in.* 246
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 149
Slaking test, average .....*min.* 65

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	4.2	Chert and sandstone fragments
40	1.0	.....
60	2.8	.....
80	5.3	White and yellow sand
120	2.2	White and yellow sand with some mica
150	2.00	White and yellow sand with some mica
200	4.8	White and yellow sand with some mica

Drying shrinkage:—Linear; wet length.....*per cent* 6.2

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*
08	36	Brownish red	1.7
06	34	Brownish red	2.2
04	32	Brownish red	3.4
02	31	Brownish red	3.8
1	30	Brownish red	4.3
3	28	Chocolate	5.0
5	22	Bluish black	6.2
7	19	Bluish black	6.8
9	17	Bluish black	7.6

Fusion test:—It deforms at cone 29.

Summary

The clay has a medium strength, a medium low bonding strength, and a medium drying shrinkage. It contains a considerable percentage residue material too coarse to pass the screen test. The total shrinkage at cone 9 is medium high. The clay is quite open burning. The very dark color of the samples carried to cone 5 and beyond suggests the possibility of reduction during burning. It is refractory.

Suggested uses: Face brick. The dark color of the burned clay and its burning conduct suggest the possibility of the iron content being abnormally high for a refractory material, even though the fusion test was satisfactory.

Sample No. 93

(Illinois Clay Products Company's mine at Deer Park)

This is a dark gray colored clay which is a semi-flint in its character. It appears to contain a notable amount of pyrites.

Water of plasticity .....*per cent* 25
Shrinkage water .....*per cent* 15.9
Pore water .....*per cent* 9.1
Modulus of rupture .....*lbs. per sq. in.* 554.7
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 302.5
Slaking test, average .....*min.* 10½
Drying shrinkage:—

	Per cent
Linear; wet length	7.2
Linear; dry length	7.8
Volume	32.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
2	7.2	Grayish white	6.0	Nearly vitreous
3	3.3	Gray	6.3	Nearly vitreous fracture
6	3.0	Gray	6.6	Nearly vitreous
8	2.2	Gray	5.5	Some fine iron spots
12	11.8?	Bluestoned	2.6	.....
13	7.3	Buff; slagged spots; blue core.	3.2	Buff exterior, blue core, numerous iron spots
15	4.6	Dark terra cotta flash outside; gray inside	4.0	..... Large iron spots overburned

Fusion test:—It deformed at cone 29.

Summary

The strength of the clay is medium high and its bonding strength is medium. The drying shrinkage is medium. The total shrinkage at cone 8 is medium high. It is practically non-porous at cone 8 and is slightly overburned at cone 13. It is a refractory clay.

Suggested uses: Refractories, especially those requiring a clay having a good strength and burning to a dense structure. Facebrick. Its slow slaking property when mixed with water is rather unfavorable for its use for stoneware and terra cotta.

Sample No. 96

(Illinois Clay Products Company's mine at Deer Park)

The sample was a hard, dark gray colored material of medium plasticity.

Water of plasticity ..... *per cent* 19
Shrinkage water ..... *per cent* 10
Pore water ..... *per cent* 9
Modulus of rupture ..... *lbs. per sq. in.* 277
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 107.3
Slaking test, average ..... *min.* 7
Screen test:—Too hard to slake.
Drying shrinkage:—

	Per cent
Linear; dry length	5.8
Linear; wet length	5.5
Volume	20.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	18	White	3.9	.....
2	17	Light cream	4.4	Earthy fracture
3	14	Light cream	...	.....
6	12	Light cream	6	Earthy fracture
9	7	Cream	6.1	Granular
12	3.0	Bluestoned; uniform gray	7	Earthy fracture
13	2.4	Bluestoned; uniform gray	6.8	Earthy fracture
15	2.4	Bluestoned; uniform gray	7.0	.....

Fusion test:—It fused about cone 31.

Summary

The strength of the clay is medium and its bonding strength is medium low. The drying shrinkage is medium. At cone 9 the total shrinkage is medium. Vitrification is nearly complete at cone 12 and there is no sign of overburning at cone 15. It is refractory.

Suggested uses: Refractories and face brick. Its slow slaking is rather unsatisfactory for stoneware and architectural terra cotta.

Sample No. 90

(Lowell Stoneware Company's pit; at Lowell)

This is a hard dark colored, i. e., gray clay which becomes very plastic when tempered with water. Its conduct when flowing through a die is very good.

Water of plasticity ..... *per cent* 20.8
Shrinkage water ..... *per cent* 8.5
Pore water ..... *per cent* 12.2
Modulus of rupture ..... *lbs. per sq. in.* 420
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 290
Slaking test, average ..... *min.* 9
Screen test:—Clay was too hard to slake.
Drying shrinkage:—

	Per cent
Linear; dry length	6.8
Linear; wet length	6.2

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	18	White	4.1	
3	14	Light cream	5.0	Earthy fracture
6	12	Light cream	5.6	Earthy fracture
9	9.5	Cream	5.7	
12	5.0	Darker cream	7.0	Granular but vitreous fracture
15	2.0	Tan exterior; bluestoned badly.	7.6	

Fusion test:—Deformation at cone 30/31.

Summary

The strength of the clay is medium high and its bonding strength is medium. Because of its hardness, the clay could not be slaked properly for the screen tests. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification is practically complete at cone 15. It is a refractory clay.

Suggested uses: Refractories, especially if good bonding power is desired. Its slow slaking property is a disadvantage for stoneware and architectural terra cotta, although otherwise it seems adapted to these uses.

Sample No. 89

(Near river bank at Lowell)

This report relates to a resampling of the deposit by Mr. Culver. This hard clay is of a gray color and it has a low degree of plasticity. The conduct of the plastic body when forced through a die is only fair.

Water of plasticity .....*per cent* 18
Shrinkage water .....*per cent* 6.6
Pore water .....*per cent* 11.3
Modulus of rupture .....*lbs. per sq. in.* 179
With 50% standard sand—Modulus of rupture .....*lbs. per sq. in.* 137.6
Slaking test, average .....*min.* 12

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	4.5	Particles of coal, rock and pyrites
40	6.8	Particles of coal, rock and pyrites
60	2.3	Particles of coal, rock and pyrites, some mica
80	1.1	Particles of clay
120	0.9	Particles of clay
150	2.0	Particles of clay
200	9.4	Particles of clay

Drying shrinkage:—Linear .....*per cent* 4.3

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	30	White	+.4	
06	27	Cream	+0.3	
04	28	Cream	−0.1	
02	28	Cream	0.26	
1	27	Cream	0.3	
3	25	Cream	1.0	
5	19	Cream with black spots	2.5	
7	19	Cream with black specks	2.2	
9	17	Black specks	2.0	
11	12	Black specks	2.5	Appears overburned

Fusion test:—Fused completely at cone 26.

Summary

The strength of the unburned clay is medium low. Its bonding strength is medium low. The amount of residues on the sieves is high. The total shrinkage at cone 9 is medium low. The vitrification is still quite incomplete at cone 11, although it has the appearance of having been overburned. It is a non-refractory clay.

Suggested uses: Stoneware, although the hardness and slow-slaking properties together with the low strength may be quite disadvantageous; face-brick.

Sample No. 95

(Herrick Clay Manufacturing Company; 1 mile east of Twin Bluffs)

This sample appears to be a mixture of clay and quartzite lumps and grains. It is a grayish or dark color.

Modulus of rupture .....*lbs. per sq. in.* 157
Slaking test, average .....*min.* 6

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	3.5	Quartz sand and pyrites
40	1.8	
60	13.9	
120	23.3	
200	2.6	

Fusion test:—Deforms at cone 27.

Summary

The strength test is medium low. The percentage of residues on the screens is high. It is refractory.

Sample No. 94

(National Fireproofing Company's pit at Twin Bluffs)

The sample is a dark gray, hard clay which contains some sandy material. When tempered with water a medium degree of plasticity may be developed. It does not flow readily through the die.

Water of plasticity ..... *per cent* 16.9
Shrinkage water ..... *per cent* 7.6
Pore water ..... *per cent* 9.2
Modulus of rupture ..... *lbs. per sq. in.* 140.6
Slaking test, average ..... *min.* 8½
Screen test:—Sample does not slake.
Drying shrinkage:—

	Per cent
Linear: dry length	4.0
Linear; wet length	3.9
Volume	15.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24.7	Gray	...	
1	25.3	Grayish white	1.0	
3	24.6	Cream	1.5	
5	21.9	Light brown	...	Specked with iron
7	22.1	Light brown	2.0	
9	22	Dark brown	2.0	
12	19	Terra cotta	2.0	Color may be due to flashing
13	16	Red brown with black spots on interior	3.0	.....
15	11	Bluestoned, gray black	5.0	.....

Oxidation conduct:—Material seems to flash very readily.
Fusion test:—It deforms at cone 31.

Summary

The strength of the clay is medium low. Its drying shrinkage is medium low. At cone 9 the total shrinkage is medium low. The clay is quite open burning, vitri-

fication being incomplete at cone 15. It is a refractory clay.

Suggested uses: The rather poor plasticity may render it difficult to form this clay readily; otherwise it is adapted to use for face brick. Although the fusion test indicates a material of refractory nature, yet the presence of numerous iron spots as indicated at the lower cones is not very satisfactory.

Sample No. 91

(National Fireproofing Company's pit; 2 miles east of Ottawa)

This is a hard clay of a dark gray color which contains a notable amount of pyrites. It is fairly plastic.

Water of plasticity ..... *per cent* 17.3
Shrinkage water ..... *per cent* 9.1
Pore water ..... *per cent* 8.2
Modulus of rupture ..... *lbs. per sq. in.* 309.5
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 236.7
Slaking test, average ..... *min.* 9

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	Trace	.....
40	0.3	Pyrite and sand
60	2.3	
80	1.1	
120	2.1	
200	2.4	

Drying shrinkage:—

	Per cent
Linear; dry length	6.8
Linear; wet length	6.3
Volume	18.9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	24.8	White	2.6	Fine specks of iron oxide
02	22.4	White	3.5	Fine specks of iron oxide
2	18.5	Grayish white	4.8	Granular
5	16.5	Grayish white	5.4	Granular
9	14.0	Grayish white	5.6	Numerous fine iron spots
13	7.9	Grayish white	7.0	.....
14	6.3	Brown red; bluestoned	5.3	Iron spots, slagged
15	16.3	Brown red; bluestoned	4.8	Iron spots, slagged

Fusion test:—Fused completely at cone 27.

Summary

The strength of the clay is medium and its bonding strength is medium. The percentage of residues left on the sieves is moderate. The drying shrinkage is medium and the total shrinkage at cone 9 is medium. Vitrification is incomplete at cone 14 and apparently the clay is overburned at cone 15. It is non-refractory.

Suggested uses: Stoneware, architectural terra cotta and sanitary ware (the presence of pyrites may make this use impossible), face brick.

Sample No. 92

(National Fireproofing Company's pit; 2 miles east of Ottawa)

This is a very hard clay of a light gray color. It has only a medium plasticity. It flows readily through a die.

Water of plasticity ..... *per cent* 17
Shrinkage water ..... *per cent* 6.9
Pore water ..... *per cent* 10.1
Modulus of rupture ..... *lbs. per sq. in.* 201
Slaking test, average ..... *min.* 5
Drying shrinkage:—

	Per cent
Linear; dry length	4.7
Volume	14

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
01	17.8	White	4.7	.....
2	17	Light cream	4.9	Earthy fracture
3	13	Light cream	6.0	Earthy fracture
6	12	Light cream	6.4	Earthy fracture
9	8	Light cream	6.2	Earthy fracture
12	4.7	Darker light buff	6.9	Very fine iron spots evenly distributed
15	6.1	Light buff; bluestoned	7.1	.....

Fusion test:—It deformed at cone 29.

Summary

The strength of the clay is medium. Its drying shrinkage is medium low. The total shrinkage at cone 9 is medium. It still has an appreciable porosity at cone 12 and apparently is slightly overburned at cone 15. It is a refractory clay.

Suggested uses: Refractories, stoneware, architectural terra cotta.

Sample No. 101

(Chicago Retort and Firebrick Company's pit, northeast of Ottawa)

This is a dark gray colored, very hard clay, which develops a fair plasticity when tempered with water. It flows only fairly well through a die.

Water of plasticity ..... *per cent* 20.0
Shrinkage water ..... *per cent* 11.5
Pore water ..... *per cent* 8.5
Modulus of rupture, maximum ..... *lbs. per sq. in.* 532
Modulus of rupture, average ..... *lbs. per sq. in.* 335
With 50% standard sand—Modulus of rupture:—14 of 20 pieces gave an average (not including values of 292.5 and 296.0) ..... *lbs. per sq. in.* 177
Slaking test, average ..... *min.* 7½
Drying shrinkage:—

	Per cent
Linear; dry length	7.0
Linear; wet length	6.5
Volume	23.5

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	19	Cream	3.6	
2	17	Cream	4.0	Earthy fracture
4	..	Cream	4.4	Earthy fracture
6	15	Darker cream	4.2	Earthy fracture
9	13	Cream	4.4	Earthy fracture
12	11	Light terra cotta; flashed	4.1	Many fine iron spots
13	12	Light terra cotta; flashed	4.6	Many fine iron spots, slagged
15	13	Buff	5.3	Golden buff, numerous iron spots

Fusion test:—It deforms at cone 29.

Summary

The tests of the clay showed it to have medium strength, but it should be noted that a single test piece gave a much higher value. The bonding test also gave two values, considerably higher than the average of a large number of pieces. The drying shrinkage is medium. The total shrinkage at cone 9 is medium. Vitrification is incomplete at cone 12, at which temperature it is still quite open. Apparently slight overburning occurs above this point. The clay is refractory.

Suggested uses: Face brick, stoneware, architectural terra cotta, sanitary ware, refractories.

Sample No. 99

(Dayton Clay Works; ½ mile south of Dayton)

The clay is of a dark gray color. It is quite sandy (see screen test), and the plasticity is low. It flows poorly through a die.

Water of plasticity ..... *per cent* 15.9
Shrinkage water ..... *per cent* 5.1
Pore water ..... *per cent* 10.8
Modulus of rupture ..... *lbs. per sq. in.* 215
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 107
Slaking test, resample ..... *min.* 22½

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	4.9	Pyrites and carbonaceous matter
40	0.3	Pyrites and quartz sand
60	5.8	White quartz sand
80	3.7	Quartz sand
120	8.4	Quartz sand
200	4.5	Darker colored sand

Drying shrinkage:—

	Per cent
Linear; dry length	4.9
Linear; wet length	4.7
Volume	9

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
08	30	Light gray white	2.0	
06	30	Light gray white	2.0	
04	30	Light gray white	2.0	
02	29	Light gray white	4.1	
1	25	Light gray white	6.2	
3	22	Light gray white	9.3	
5	..	Light gray white; iron specks	8.3	
6	23	Slightly darker	...	
7	..	Slightly darker	6.2	
9	19	Slightly darker	...	
12	16	Terra cotta; flashed	...	Numerous iron spots
15	21	Terra cotta; flashed	...	Many large iron spots

Fusion test:—It fused at cone 30.

Summary

The clay has a medium strength, and a medium low bonding strength. The amount of screen residues is high. The drying shrinkage is medium low. The minimum porosity was reached at cone 12 and it appeared to overburn at cone 15. The fusion test indicates a refractory clay.

Suggested uses: Face brick. Certain types of refractories.

Sample No. 102

(Resampled by H. E. Culver)

(Dayton Clay Works; ½ mile south of Dayton)

This is a hard clay which is dark gray, nearly black in color. When tempered with water, it becomes very plastic and flows through a die satisfactorily.

Water of plasticity ..... *per cent* 33
Shrinkage water ..... *per cent* 12
Pore water ..... *per cent* 21
Modulus of rupture ..... *lbs. per sq. in.* 297
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 223
Slaking test, average ..... *min.* 13

Screen test:—

Mesh (Sample slaked badly.)	Residue *Per cent*	Character of residue
20	0.8	Sand
40	0.3	
60	1.9	Clay particles
80	0.4	
120	1.0	
150	0.6	
200	0.9	

Drying shrinkage:—Linear; wet length ..... *per cent* 6.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		*Per cent*
08	29	Salmon	3.0
06	23	Brownish red	4.4
04	15	Darker	6.3
02	12	Chocolate	7.6
1	7	Gray	9.2
3	1.2	Greenish black	9.4
5	Overburned		

Fusion test:—Completely fused at cone 27. Vesicular.

Summary

The clay has a medium strength and a medium bonding strength. It slakes rather poorly and leaves a moderate amount of residues upon the screens. The drying shrinkage is medium. The clay has a short heat range. It reaches a minimum porosity at cone 3 and is overburned at cone 5. It is non-refractory.

Suggested uses: Brick and tile.

Sample No. 129

(Resampled by Mr. Culver)

(Chicago Firebrick Company's shaft; 2 miles east of Marseilles)

This clay has a dark gray color. It is very hard. When tempered with water, it has good plasticity. Its conduct when squeezed through a die is fair.

Water of plasticity ..... *per cent* 32.9
Shrinkage water ..... *per cent* 21.7
Pore water ..... *per cent* 11.2
Modulus of rupture, maximum ..... *lbs. per sq. in.* 900
Modulus of rupture, average ..... *lbs. per sq. in.* 795
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 247
Slaking test, 2nd sample ..... *min.* 34

Screen test:—

Mesh	Residue	Character of residue
	Per cent	
20	1.2	Quartz, coal, pyrites
40	0.4	.....
60	0.8	.....
80	1.3	Particles of hard clay
120	0.4	Particles of hard clay
150	0.3	Particles of hard clay
200	1.27	Particles of hard clay

Drying shrinkage:—

	Per cent
Linear; dry length	12.5
Linear; wet length	10.0

Burning test:—

Cone	Porosity	Color	Burning shrinkage
	Per cent		*Per cent*
08	22	Cream	1.5
06	20	Cream	2.1
04	13	Grayish	3.0
02	12	Grayish	4.0
1	7	Grayish	4.2
3	8	Grayish	4.4
4	Overburned	Iron spots	...

Fusion test:—It deforms at cone 27/28.

Summary

The strength of this clay as determined by taking the average of nineteen of twenty-one test pieces is medium high. It should be noted that the maximum strength test of 900 pounds per square inch was obtained with four test pieces. The bonding test was medium. The amount of residues left upon the screens was moderate. The drying shrinkage was medium high and the total shrinkage at cone 1 was high. The sample appeared to be overburned at cone 4. The fusion test indicates a refractory clay.

Sample No. 130-a

(Streator Clay Manufacturing Company's shaft; 2 miles south of Streator)

This is a dark colored, very hard clay, which contains much pyrite. Its slaking time averages 6½ minutes. It is completely fused at cone 25.

Sample No. 130-b

(Streator Clay Manufacturing Company's shaft; 2 miles south of Streator)

This is a dark colored, i. e., grayish, very hard clay. The average time of the slaking test was nineteen minutes. It is completely fused at cone 25.

Sample No. 131

(Spring Lake Coal Company's shaft at Kangley)

This is a hard, greenish-gray colored clay, which is stained with iron oxide. It has a conchoidal fracture. When tempered with water, a medium plasticity may be developed. Its conduct when forced through a die is satisfactory. The occurrence of gypsum crystals in the clay was noted.

Water of plasticity ..... *per cent* 29.7
Shrinkage water ..... *per cent* 13.3
Pore water ..... *per cent* 16.4
Modulus of rupture ..... *lbs. per sq. in.* 361.8
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 192.6
Slaking test, average ..... *min.* 15

Drying shrinkage:—

	Per cent
Linear	5.7
Volume	20.0

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	0.9	Particles of shale, pyrite, and coal
14	1.0	
20	1.1	
35	2.6	
48	1.18	
65	1.0	
100	0.8	
150	0.65	
200	0.50	

Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
04	10.3	Terra cotta	13.9	Scummed by efflorescent salts
01	1.75	Terra cotta	15.3	Vitreous glassy fracture
3	0.9	Reddish brown	15.3	Vitreous glassy fracture
5	4.8	Brown	....	Overburned, bloated
7	11.8	Brown	....	Overburned, bloated

Soluble salts:—Salts appear on the pieces after burning.
Fusion test:—It fused at cone 25.

Summary

The strength of the clay is medium. Its bonding strength is medium low. The amount of coarse particles is moderate and the fractions are quite evenly distributed. The total shrinkage at cone 3 is high. The clay vitrifies rapidly at a low temperature and is overburned at cone 5, thus having a very limited heat range. It is non-refractory.

Suggested uses: Common brick.

GRUNDY COUNTY

An exceptional thickness of clay is found in the depression formerly occupied by Goose Lake. Lenses of this clay are of a semi-flinty nature and thin layers of coal are interbedded with it. This coal varies in thickness, and at the west end will total 6 or 7 feet. The total thickness of the clay is reported to vary from 30 to 40 feet and the overburden over the 200 acre deposit ranges from practically nothing to 6 or 8 feet with an average of about 3 feet. A drilling 30 feet deep did not reach the bottom of the clay. "Islands" of rock are found in the clay and suggest its accumulation in solution basins in the crystalline Richmond limestone which outcrops at the north; at least these basins were in some way partly separated from the main "Coal Measures" sea at the south. Fig. 56 is a view of the clay pit at the west end of the Goose Lake area.

A face exposed in the bank of a small test pit is as follows:

FIG. 56. View of the clay pit at the west end of the Goose Lake area in Grundy County.

Section of upper part of Goose Lake clay

		Thickness Ft.	In.
5.	Peaty soil and peat	..	8 to 10
4.	Sandstone, local thin lenses	..	0 to 3
3.	Fireclay, flint or semi-flint, drab, stained by iron and showing colorings of carbon (Sample No. 133)	1	..
2.	Shale, stained black by carbon	..	6
1.	Clay, drab gray with yellow stains of iron oxide (Sample No. 134)	3	6

The upper "flint" or "semi-flint" is underlain by a thin coal which is in turn above a plastic clay of lower refractory value.

An additional sample, known as No. X, which was obtained from a pit on the Anderson farm in Goose Lake Township, Grundy County, was collected and shipped to the Survey by D. C. Haeger. It is known as No. 1 fire clay, according to Mr. Haeger. The clay lies in a bed 5 feet in thickness and is covered by 20 to 24 feet of soft stone, 30 to 36 feet of sandstone, and 16 inches of black soil.

Results of tests on sample No. X are given on page 144.

RESULTS OF TESTS

GRUNDY COUNTY

Sample No. 133

(Clay pit at the west end of the Goose Lake area)

This is a drab colored, flinty clay, stained with iron. When ground and tempered with water, it develops a medium plasticity.

Water of plasticity ..... *per cent* 18.2
Shrinkage water ..... *per cent* 8.6
Pore water ..... *per cent* 9.6
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 59.6
Slaking test, average ..... *min.* 3

Screen test:—

Mesh	Residue *Per cent*	Character of residue
40	0.14	Particles of hard clay and sand
60	0.24	
80	0.30	
120	0.64	
200	0.25	

Drying shrinkage:—

	Per cent
Linear; dry length	3.6
Linear; wet length	3.5
Volume	16.6

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
02	24	White	2.8	Earthy fracture
01	24.3	White	3.3	
3	22	White	4.2	
6	21	White	4.3	
9	17	Cream white	5.0	
12	12	Cream white	6.4	
13	8	Cream white	7.2	Granular fracture; numerous flinty particles and fine iron stain
15	6	Buff; lightly bluestoned	8.3	

Fusion test:—Deforms between cones 30 and 31.

Summary

The bonding strength of the clay is low. The drying shrinkage is medium low. The total shrinkage at cone 9 is medium. It has a low porosity at cone 15. It is a refractory clay.

Suggested uses: Refractories.

Sample No. 134

(Clay pit at west end of Goose Lake area)

This is a clay of medium hardness, and gray colored but stained with yellow. Tempered with water, it has a medium degree of plasticity and shows a tendency to laminate when forced through a die.

Water of plasticity ..... *per cent* 31.8
Shrinkage water ..... *per cent* 18.5
Pore water ..... *per cent* 13.3
Modulus of rupture ..... *lbs. per sq. in.* 442
With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 194
Slaking test, average ..... *min.* 14

Screen test:—

Mesh	Residue *Per cent*	Character of residue
20	0.1	Sand
60	0.7	Sand
80	0.1	Sand
120	0.9	Sand
200	0.3	Sand

Drying shrinkage:—

	Per cent
Linear; dry length	7.6
Linear; wet length	7.1

Burning test:—

Cone	Porosity *Per cent*	Color	Burning shrinkage *Per cent*	Remarks
04	30	Cream white	1.4	
02	26	Cream white	3.0	
2	17	Cream white	5.4	Earthy fracture
5	15	Cream white	6.0	
9	11	Cream white	6.7	
13	4.1	Light gray	7.2	Vitreous; not glassy
14	4.0	.....	6.4	.....
15	4.3	Light brown exterior; bluestoned or light gray	6.3	.....

Fusion test:—Deforms at cone 28.

Summary

The clay has a medium high strength and a medium low bonding strength. The drying shrinkage is medium. The amount of screen residues is low. At cone 9 the total shrinkage is medium high. It reaches a low degree of porosity at cone 13 and shows no sign of overburning at cone 15. It is a refractory clay.

Suggested uses: Refractories, architectural terra cotta, stoneware, sanitary ware, face brick.

Sample No. X

(Anderson farm in Goose Lake township)

This is a drab colored, flinty clay, which develops a medium plasticity when tempered with water—i. e., it is rather sandy or grainy. The plastic mass laminates badly when squeezed through a die.

Water of plasticity	*per cent* 26.6
Shrinkage water	*per cent* 14.6
Pore water	*per cent* 12.0
Modulus of rupture	*lbs. per sq. in.* 317.4
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.* 202.3

Screen test:—

Mesh	Residue *Per cent*	Character of residue
10	2.9	
14	1.8	
20	2.8	Fragments of coal and shale
35	8.5	
48	5.5	
65	5.4	

100	3.9	Fragments of coal and shale, and some mica
150	2.7	
200	3.0	

Drying shrinkage:—

	Per cent
Linear	6.2
Volume	26

Burning test:—

Cone	Porosity *Per cent*	Color	Hardness	Total shrinkage *Per cent*	Remarks
04	10.0	Gray	Very hard	12	Granular fracture
01	6.9	Gray	Very hard	13	.....
1	12.5	Gray	Very hard	12	.....
3	6.8	Gray	Very hard	12.7	.....
5	2.4	Gray	Very hard	12.9	Slightly bluestoned
7	1.3	Gray	Very hard	12.9	.....
9	0.4	Gray	Very hard	12.9	.....
12	0.5	Gray	Very hard	13.1	.....
14	0.5	Gray	Very hard	12.2	Some iron specks

Fusion test:—It deforms at cone 28.

Summary

The clay has a medium strength and bonding strength. The air shrinkage and total shrinkage are medium. It is almost completely vitrified at cone 5 and shows no signs of overburning throughout the firing range. It is refractory.

Suggested uses: Refractories, particularly those of a close texture.

JOHNSON COUNTY

About two miles southeast of Ozark station is a deposit of Pottsville oil shale or cannel coal which has been investigated by the Survey. Perhaps the best typical exposure of this deposit and the associated strata is that on the Stone land, a section of which is here given:

Section of oil shale measured in a test pit on the Frank Stone land in the NW. ¼ NW. ¼ sec. 35, T. 11 S., R. 4 E.

		Thickness *Ft.*	*In.*
8.	Soil, yellow	1 to 5	..
7.	Shale, chocolate, siliceous	4	2
6.	Mud, red, merely a streak	..	..
5.	Oil shale	2	9
4.	Coal, bituminous	..	1½
3.	Coal, cannel	..	4
2.	Coal, bituminous, with peacock-colored blotches	..	2
1.	"Fire clay," white	5+	..

In connection with the sampling of the oil shale a sample of the underlying clay was taken and tested with the results that follow.

Sample No. C-18—1

(Sample taken from below the cannel coal near Ozark in sec. 35, T. 11 S., R. 4 E.)

This sample is medium hard, gray colored clay, mottled with brown, which latter color may be due to the presence of organic matter. It has rather poor plasticity.

Water of plasticity ..... *per cent* 22.09
Shrinkage water ..... *per cent* 9.20
Pore water ..... *per cent* 12.89
Modulus of rupture ..... *lbs. per sq. in.* 147.3
Slaking test, average ..... *min.* 8
Drying shrinkage, linear ..... *per cent* 4.4
Burning test:—

Cone	Porosity *Per cent*	Color	Total shrinkage *Per cent*	Remarks
04	18.7	Light tan	8.3	
01	16.4	Light tan	7.3	Earthy fracture
1	17.9	Gray	9	
5	9.4	Dark gray	11.5	
7	3.1	Dark gray	7	Shows signs of overburning

Fusion test:—It fuses at cone 16.

Summary

The clay has a medium low strength and a medium drying shrinkage. The burning shrinkage at cone 5 is medium high. It seems to be overburned at cone 7. The trial pieces have the appearance of having been subjected to reducing conditions at and above cone 5. The clay is non-refractory, in fact, it is very fusible.

Suggested uses: Brick.

Tabulation of Certain Physical Tests

A knowledge of certain of the physical tests of a clay will enable the experienced person to determine very quickly whether it is likely to be of value for a specific purpose. Accordingly there are grouped in the following paragraphs classifications of the clays examined according to the results obtained in the more significant tests. A full explanation of the methods of testing and the interpretation has been given elsewhere.

Slaking test:—The samples which required more than thirty minutes for slaking according to the standard test were: Nos. 22, 38, 44 (169) 55, 58. 59, 60, 97, 98, 100, 129, 136.

Fusion test:—The samples which fused below cone 27 were: Nos. 17, 37-a, 41, 42, 47, 50, 52, 54, 55, 56, 57, 58, 61, 62, 67, 69, 70, 73-a, 74, 75-a, 75-b, 79, 80, 81, 82, 83, 84, 85, 86, 89, 91, 97, 102, 130-a, 131, 136.

The samples which fused between cones 27 and 32 inclusive were: Nos. 9, 16, 22, 23, 25, 27, 28, 29, 30, 37, 38, 44, 45 (1678), 46, 48, 51, 53, 59, 60, 65, 66, 71, 73-b, 73-c, 75, 77, 78, 87, 88, 90, 92, 93, 94, 95, 96, 98, 99, 100, 101, 121, 122, 129, 133, 134, X.

The samples which fused at cones 33 and above were: Nos. 11, 18, 26.

Porosities:—A grouping of the samples in accordance with their porosities at various cones is given in the following table:

5% or less at or below cone 5	5% or less between cones 5 and 9	5% or less between cones 9 and 12	5% or less between cones 12 and 15	10% or more at cone 12 or above
23	F	G	18	16
26	25	K[3]	38	46
29	27	49	54	50
30	28	51	56	70
42	37	73-a	65	75-a
55	37-a	75	71	79
57	52	90	74	84
58	66	96	77	89
59	81	97	87	94
60	86	.....	92	98*
61	121	.....	.....	99
62	122	.....	134	101
67	.....	.....	.....	.....
69	.....	.....	.....	.....
73-b	.....	.....	.....	.....
73-c	.....	.....	.....	.....
82	.....	.....	.....	.....
83	.....	.....	.....	.....
85	.....	.....	.....	.....
88	.....	.....	.....	.....
93	.....	.....	.....	.....
102	.....	.....	.....	.....
131	.....	.....	.....	.....

*Probably.

Strength tests:—The following are the transverse strength tests of the various clays reported in terms of the moduli of rupture in pounds per square inch. The symbol "p" is used to indicate results obtained in testing the clay only. The symbol "b" indicates the test of a mixture of equal parts of standard sand and clay; that is to say, the "bonding strength."

Sample	Below 200 lbs. per sq. in.		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
9	.....	104.4	.....	.....	.....	.....
11	43.4	.....	.....	.....	.....	.....
16	64.1	.....	.....	.....	.....	.....
17	180.9	.....	.....	.....	.....	.....
23	.....	.....	311.2	302.3	.....	.....
25	141.2	131.2	.....	.....	.....	.....
26	.....	137.5	259	.....	.....	.....
27	.....	120.9	265	.....	.....	.....
28	192	151.8	.....	.....	.....	.....
29	.....	286.1	.....	.....	.....	.....
30	.....	.....	345	229	.....	.....

Sample	Below 200 lbs. per sq. in.		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
37	.....	.....	.....	249.7	487.2	.....
37-a	.....	.....	240.7	238.7	.....	.....
38	164.8	.....	.....	.....	.....	.....
42	.....	.....	283.1	.....	.....	.....
44	.....	.....	.....	325.6	465.6	.....
45	.....	.....	.....	299.5	526.6	.....
46	.....	.....	217.4	214	.....	.....
47	.....	.....	365.8	.....	.....	.....
49	.....	189.5	369.2	.....	.....	.....
50	.....	.....	207	275.5	.....	.....
51	.....	199	.....	.....	446.8	.....
52	.....	.....	380.2	243.9	.....	.....
53	120.2	103.1	.....	.....	.....	.....
54	.....	.....	250	250	.....	.....
55	172.5	145.1	.....	.....	.....	.....
56	.....	.....	.....	231.8	462	.....
57	.....	.....	.....	370	565.5	.....
58	165.7	124.6	.....	.....	.....	.....
59	.....	169.8	.....	.....	589	.....
60	.....	164.5	.....	.....	427	.....
61	.....	.....	.....	372.7	567	.....
65	.....	.....	240.8	.....	.....	.....
66	.....	.....	.....	.....	414.5	.....
67	.....	.....	303.8	248.7	.....	.....
69	.....	.....	.....	242	498.3	.....
70	.....	.....	.....	302.8	609	.....
71	144	.....	328	.....	.....	.....
73-a	.....	.....	352.2	.....	.....	.....
73-b	.....	.....	356.5	.....	.....	.....
73-c	.....	.....	339.3	.....	.....	.....
74	.....	.....	221.8	214.9	.....	.....
75	.....	.....	295.6	.....	.....	.....
75-a	.....	192	269.6	.....	.....	.....
75-b	.....	199.6	263	.....	.....	.....
77	.....	.....	320	261	.....	.....
78	.....	.....	325.8	209.4	.....	.....
79	.....	119.5	287.3	.....	.....	.....
80	.....	.....	.....	.....	445.4	.....
82	.....	185.2	.....	.....	484.8	.....
83	.....	.....	.....	329	664	.....
84	.....	.....	214	.....	.....	.....
85	.....	.....	386.7	.....	.....	.....
86	190.2	.....	.....	.....	.....	.....
87	.....	.....	.....	290.3	497.6	.....
88	.....	.....	.....	243	.....	.....
89	179	137.6	.....	.....	.....	.....

Sample	Below 200 lbs. per sq. in		Between 200 and 400 lbs. per sq. in.		Above 400 lbs. per sq. in.	
	p	b	p	b	p	b
90	.....	.....	.....	290	420	.....
91	.....	.....	309.5	236.7	.....	.....
92	.....	.....	201	.....	.....	.....
93	.....	.....	302.5	.....	554.7	.....
94	140.6	.....	.....	.....	.....	.....
96	.....	107.3	277	.....	.....	.....
97	.....	.....	.....	201	565	.....
98	.....	149	.....	246	.....	.....
99	.....	107	215	.....	.....	.....
100	.....	.....	.....	222	475	.....
101	.....	177	.....	.....	532	.....
102	.....	.....	297	223	.....	.....
121	191	123.3	.....	.....	.....	.....
122	177	136.5	.....	.....	.....	.....
129	.....	.....	.....	247	795	.....
131	.....	192.6	361.8	.....	.....	.....
133	.....	59.6	.....	.....	.....	.....
134	.....	194	.....	.....	442	.....

SUMMARY

Grouping of Clays According to Uses

In the following summary the clays have been grouped according to uses to which they seem to be adapted. It is to be understood that the arrangement is based solely upon the data given, and not upon special tests.

Refractory clays burning to a porosity of 5 per cent or less at cone temperatures not exceeding cone 9:

Samples F, G, K_3, Nos. 23, 25, 26, 27, 28, 29, 30, 37, 37a, 55, 59, 66, 73c, 88, 93, 121, 122.

Refractory clays which have a porosity of more than 5 per cent below cone 9:

Nos. 16, 18, 22, 38, 44, 45, 46, 49, 51, 53, 54, 56, 71, 75, 77, 78, 80, 87, 90, 92, 94, 96, 97, 98, 99, 100, 101, 129, 133, 134.

Stoneware clays:

Nos. 9, 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52, 54, 56, 57, 65, 66, 70, 71, 73a, 73c, 74, 75, 75b, 77, 78, 79, 80, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 100, 101, 121, 122, 134.

Architectural terra cotta clays:

Nos. 9, 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52, 53 54, 55, 56, 57, 58, 60, 65, 66, 70, 71, 73a, 73c, 74, 75, 75b, 77, 78, 79, 80, 84, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 100, 101, 121, 122, 134.

Sewer pipe clays:

Nos. 50, 57, 59, 60, 65, 67, 73b, 83, 86.

Face brick clays:

Nos. 42, 45, 47, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 61, 62, 65, 67, 70, 71, 73a, 73b, 73c, 74, 75b, 77, 78, 79, 80, 83, 84, 85, 86, 87, 88, 89, 91, 92, 93, 96, 97, 98, 99, 100, 101, 134.

Common brick, tile, etc.:

Nos. 61, 62, 69, 75a, 81, 82, 86, 102, 131, 136.

Sanitary ware clays:

Nos. 23, 25, 26, 28, 29, 30, 37, 37a, 38, 41, 42, 44, 47, 49, 51, 52, 53, 54, 55, 56, 57, 65, 66, 70, 71, 73a, 73c, 74, 75b, 77, 78, 79, 80, 85, 87, 88, 89, 90, 91, 92, 93, 96, 97, 98, 99, 100, 101, 134.